# modern castings

AFS JUNE, 1959

TWO ARTICLES ON COBALT 60 RADIOGRAPHY

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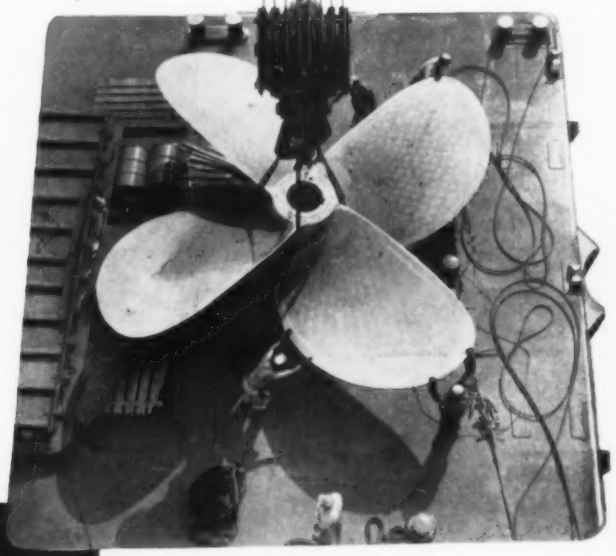
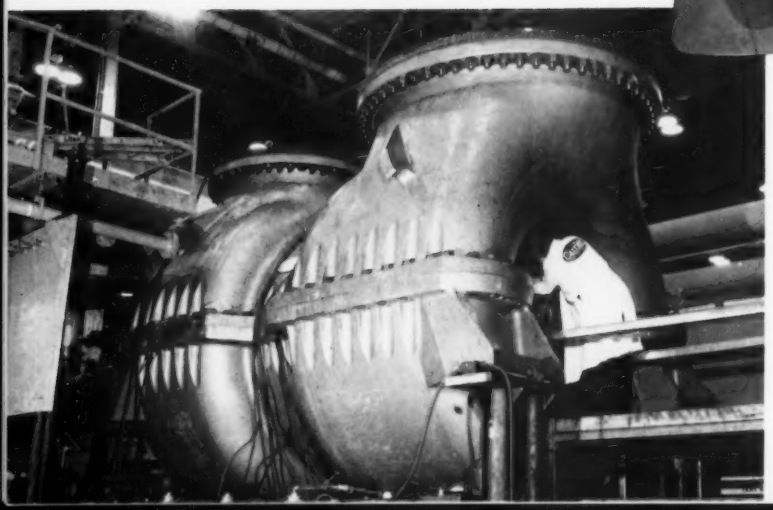
**Improving casting quality through inspection** . . . . . **p 73**

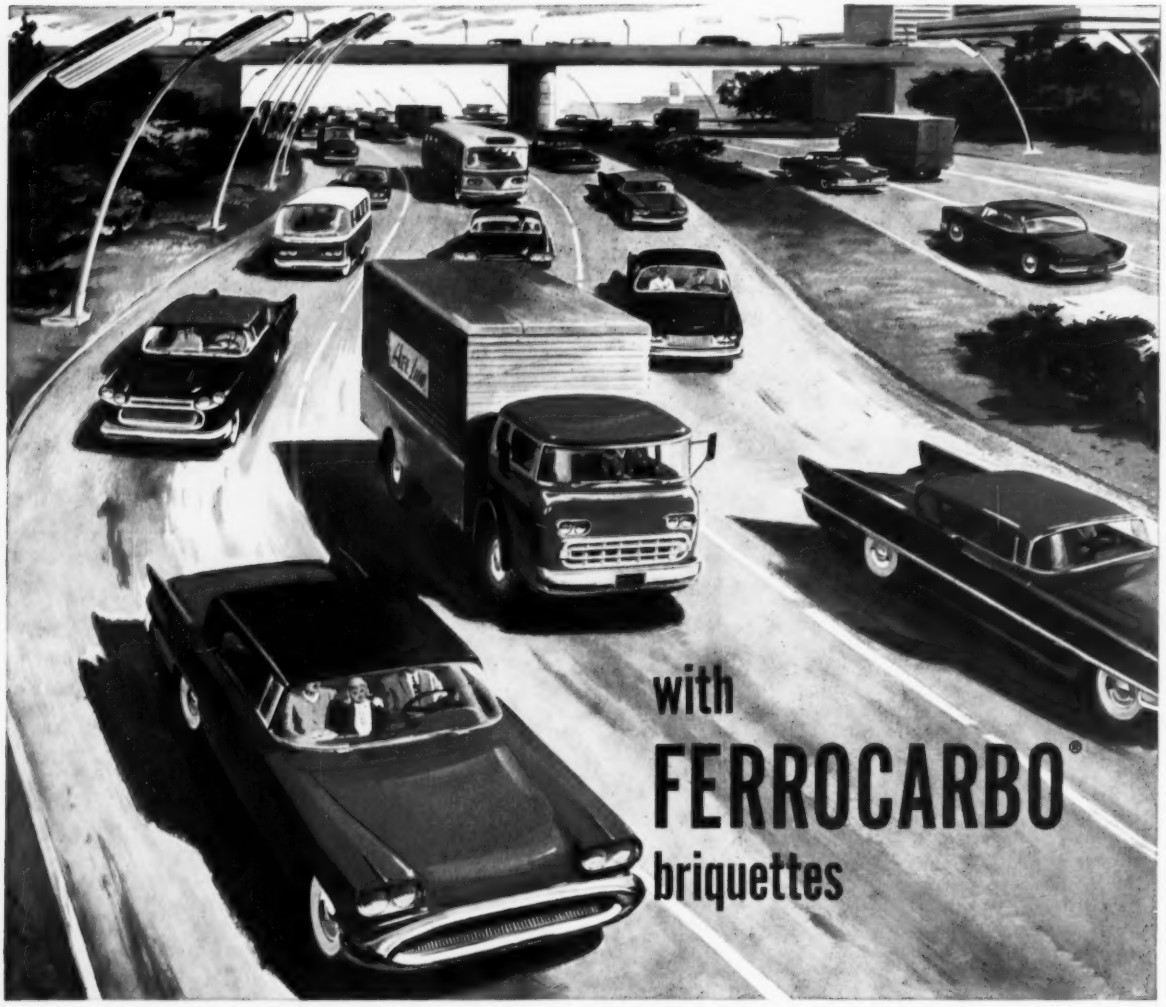
Propellers for supertankers are supercastings . . . . . p 31





**The second greatest market for metalcastings:** air conditioning . . p 32

# STRONGER CASTINGS FOR 6,000,000 AUTOS




The automotive industry is the world's largest consumer of gray iron and malleable iron castings. In 1958, 1,427,000 net tons of gray iron and 300,000 net tons of malleable iron were cast for some 5,000,000 passenger cars, trucks and buses. In 1959 this figure may exceed 6,000,000 *in passenger cars alone.* This gigantic industry is a prime user of FERROCARBO briquettes, the exclusive patented cupola additive by Carborundum. FERROCARBO results in finer-grained, denser, and stronger castings required by today's high-powered vehicles. FERROCARBO-treated castings are more machinable thus lowering manufacturing costs. See that FERROCARBO is in your production picture for *premium* castings at *no extra cost.*

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Circle No. 145, Page 141-142

june, 1959
vol. 35, no. 6

# modern castings

## the technical magazine of the metalcasting industry

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## future meetings and exhibits

JUNE

1-2 . . New York University, College of Engineering, *Conference on Vacuum Metallurgy*. University Heights, N.Y.

9-12 . . Material Handling Institute, *Exposition*. Public Auditorium, Cleveland.

11-12 . . AFS *Chapter Officers Conference*. AFS Headquarters, Des Plaines, Ill., and Sherman Hotel, Chicago.

15 . . AFS T&RI Research Committee, *Annual Meeting*. Chalfonte-Haddon Hall, Atlantic City, N.J.

16-19 . . Cornell University, *Industrial Engineering Seminars*. Ithaca, N. Y.

18-20 . . AFS *Foundry Instructors Seminar*. University of Illinois, Urbana, Ill.

21-23 . . Alloy Casting Institute, *Annual Meeting*. The Homestead, Hot Springs, Va.

21-26 . . American Society for Testing Materials, *Annual Meeting*. Chalfonte-Haddon Hall, Atlantic City, N.J.

22-26 . . Air Pollution Control Association, *Annual Meeting*. Hotel Statler, Los Angeles.

22-26 . . University of Michigan, *Engineering Summer Conference*: Application of Stress Analysis to Design and Metallurgy. Ann Arbor, Mich.

22-26 . . *Gordon Research Conference*: Physical Metallurgy. Kimball Union Academy, Meriden, N. H.

25-27 . . *Penn State Foundry Conference*. Pennsylvania State University, University Park, Pa.

29-July 3 . . New York University, *Ductile Iron Course*. University Heights, N. Y.

SEPTEMBER

21-22 . . Steel Founders' Society of America, *Fall Meeting*. The Homestead, Hot Springs, Va.

24-26 . . *AFS Missouri Valley Regional Foundry Conference*. University of Missouri, School of Mines & Metallurgy, Rolla, Mo.

28-Oct. 1 . . Association of Iron and Steel Engineers, *Annual Convention*. Sherman Hotel, Chicago.

OCTOBER

1-2 . . *Niagara Regional Foundry Conference*. Drummons Country Club, Syracuse, N. Y.

2-3 . . AFS *Northwest Regional Foundry Conference*. Benjamin Franklin Hotel, Seattle.

3-10 . . International Committee of Foundry Technical Associations, *International Foundry Congress*. Madrid, Spain.

7-9 . . Gray Iron Founders' Society, *Annual Meeting*. Fairmont Hotel, San Francisco.

8-9 . . AFS *Michigan Regional Foundry Conference*. Pantlind Hotel, Grand Rapides, Mich.

11-16 . . American Society for Testing Materials, *Pacific Area National Meeting & Exhibit*. Sheraton Palace Hotel, San Francisco.

15-17 . . Foundry Equipment Manufacturers Association, *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

16-17 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

21 . . Cast Bronze Bearing Institute, *Annual Meeting*. Bedford Springs Hotel, Bedford, Pa.

22-23 . . AFS *Ohio Regional Foundry Conference*. Deshler-Hilton Hotel, Columbus, Ohio.

23-24 . . Non-Ferrous Founders' Society, *Annual Meeting*. Bedford Springs Hotel, Bedford, Pa.

29-30 . . AFS *Purdue Metals Casting Conference*. Purdue University, West Lafayette, Ind.

NOVEMBER

2-6 . . American Society for Metals, *National Metal Exposition & Congress*. International Amphitheatre, Chicago.

6-7 . . National Foundry Association, *Annual Meeting*. Roosevelt Hotel, New York.

9-11 . . Steel Founders' Society of America, *Technical & Operating Conference*. Carter Hotel, Cleveland.

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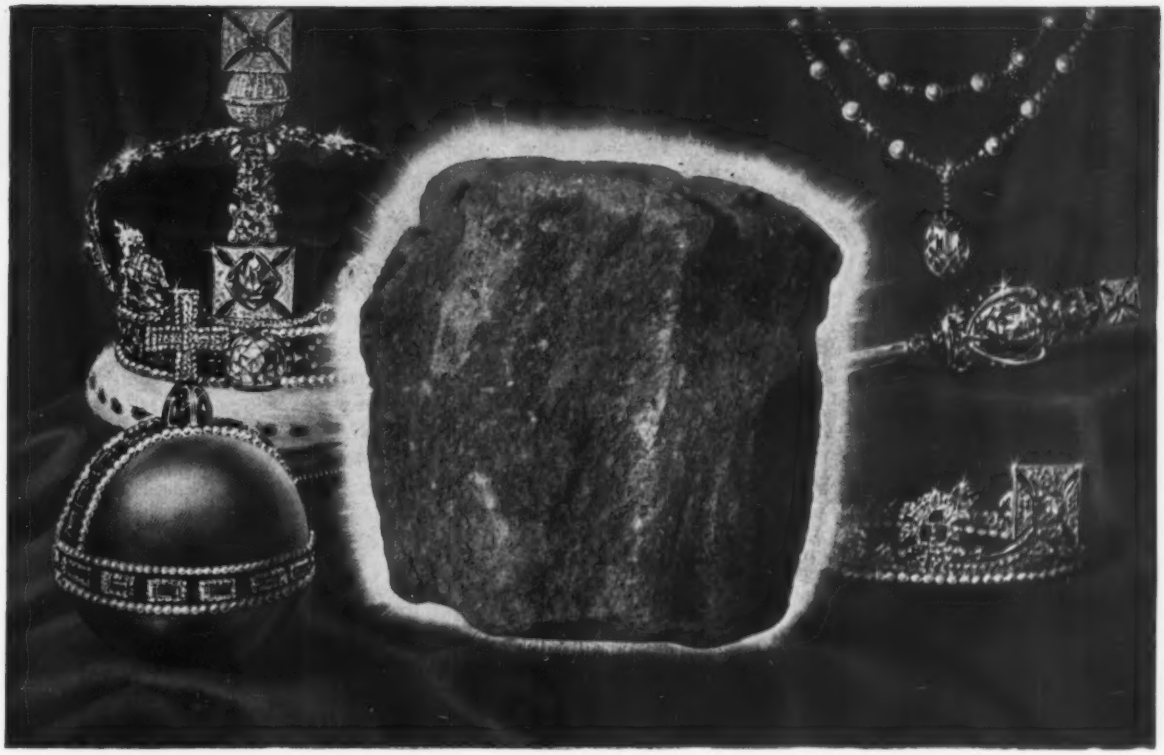

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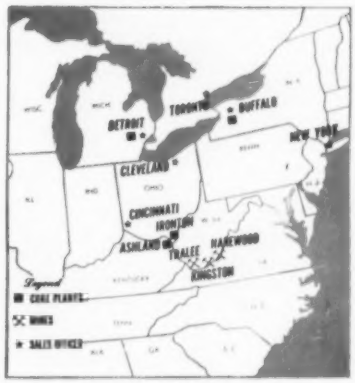


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Allied Chemical

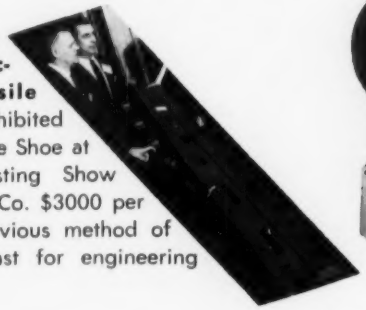
# the editor's report

by Jack Schaum

■ **A new vacuum die casting technique** was introduced to the industry at the Die Casting and Permanent Mold Luncheon, AFS Castings Congress, by its inventor, G. R. Morton. By literally exploding the air out of the die cavity simultaneously with the shot of metal entering it, high speed production is obtained with a relatively small vacuum pumping system. Aluminum, zinc and magnesium base alloys are being successfully cast in the equipment.

■ **Talk about diversification!** Hampden Brass & Aluminum Co., Springfield, Mass., exhibited at the Engineered Castings Show aluminum castings made by sand, permanent mold and die casting, plus . . . helicopter countervanes made by pressure casting an epoxy resin-fiberglas mix! So don't limit your casting thinking to metallic materials.

■ **"All our weldments have been converted to castings,"** said G. M. Kutchman, W. A. Kates Co., manufacturer of flow regulators. In looking for new sources of castings at the Engineered Casting Show, Mr. Kutchman pointed out that his company buys yearly about 25,000 castings made of carbon steel, stainless steel, titanium, zirconium, tantalum and yes, even illium.



■ **This chilled ductile iron missile launcher rail** exhibited by American Brake Shoe at Engineered Casting Show saved the Martin Co. $3000 per unit over the previous method of fabrication. So cast for engineering economy.

■ **Highlights of talk by T. O. Kuivinen,** The Cooper-Bessemer Corp., at the Ductile and Gray Iron Round Table Luncheon, 63d Castings Congress, are worth noting . . . "Eliminate the factor of ignorance in casting design and you can reduce the imposing factor of safety placed on castings . . . Cast parts must be producible as well as functional . . . Designers lost faith in castings because of poor performance . . . Castings must meet the ultimate goal—successful performance of finished product on part of user."

■ **At Light Metals Round Table Lunch,** 63d Castings Congress, some rather strong opinions were expressed on futility of casting test bars that mean anything. Some comments were . . . foundrymen pour test bars only because specs require them . . . separately cast test bars tell nothing about quality of the casting . . . cutting test bars from critical areas is expensive and only tells you **how strong the casting was.**

■ **Here's how Western Electric Co. is using 400,000 castings yearly.** Every time a telephone cable is spliced, the splice is encased in a 2-piece aluminum die casting which is pressure-tight to retain the gas in the cable.

■ **American Steel Foundries** exhibited at the Engineered Castings Show a 220-lb steel "fifth wheel" for tractor-trailer truck. This is claimed to be the largest steel casting made in a shell mold. It also uses the largest shell molding machine ever built. Plate size is 54x94 in.

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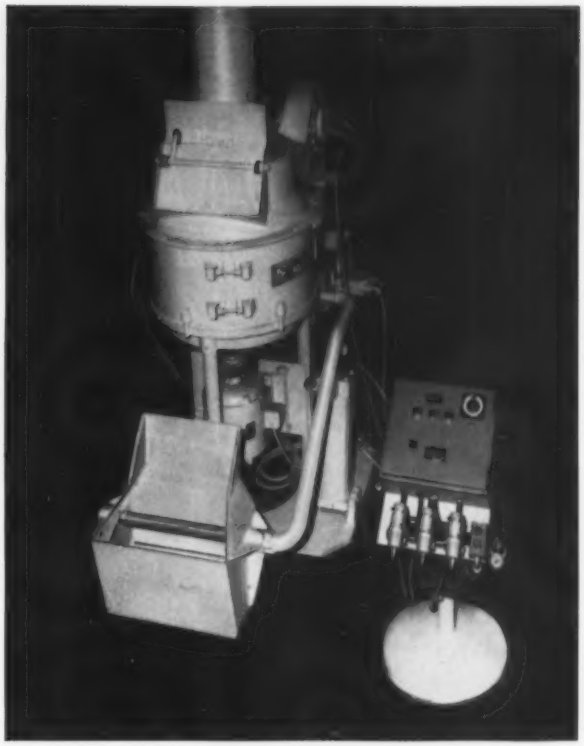
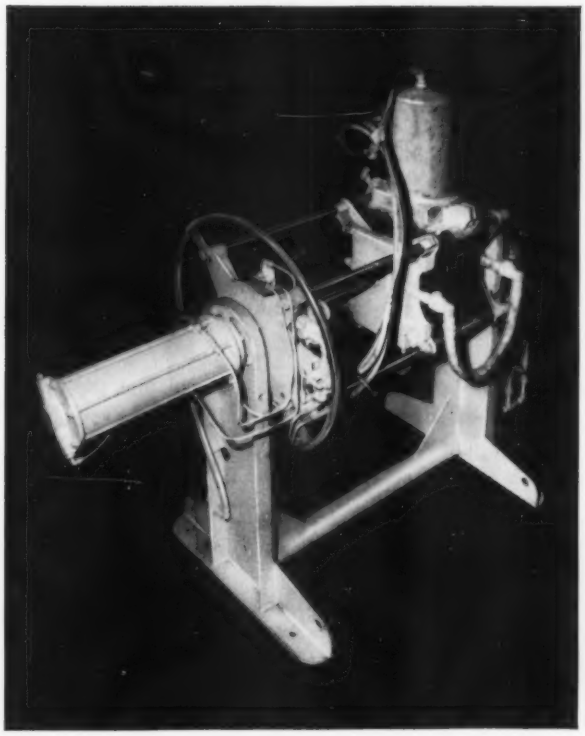


# NEW SHELL CORE TEAM



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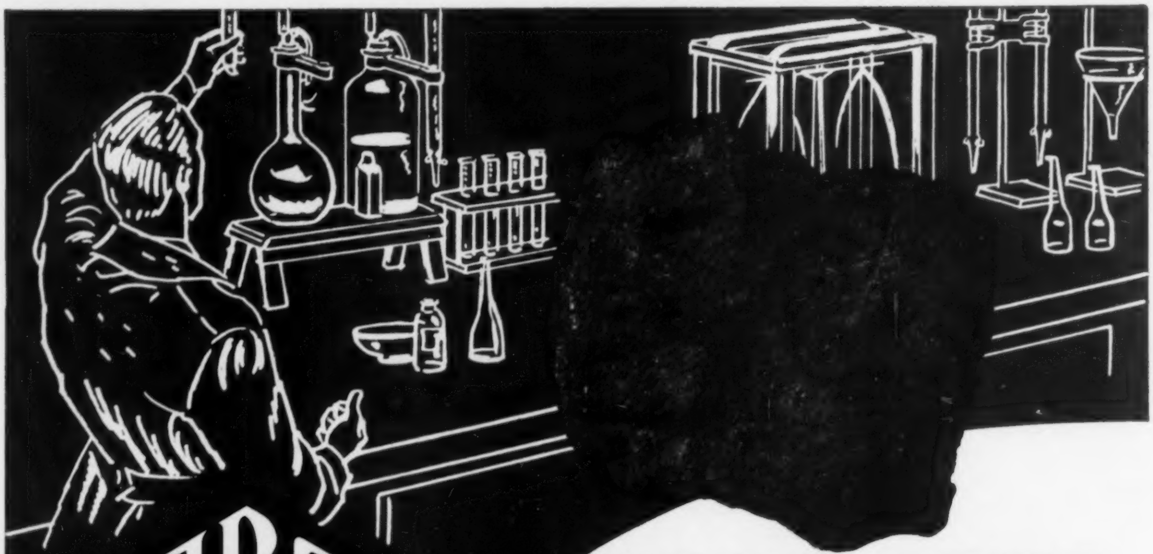


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- **MODERN PLANT FACILITIES** which have been constantly improved and expanded.
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- **CUPOLA TESTING** to forecast coke performance.
- **CAREFUL SCREENING** to insure correct sizing for any cupola operation.
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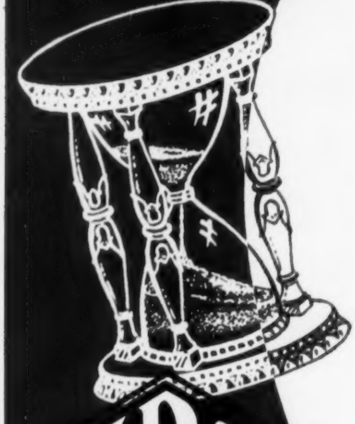
Whatever the requirements of your operation, you will find the right size . . . the right type of ABC Foundry Coke to give you the very best melting performance. Your inquiries are invited.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Circle No. 148, Page 141-142

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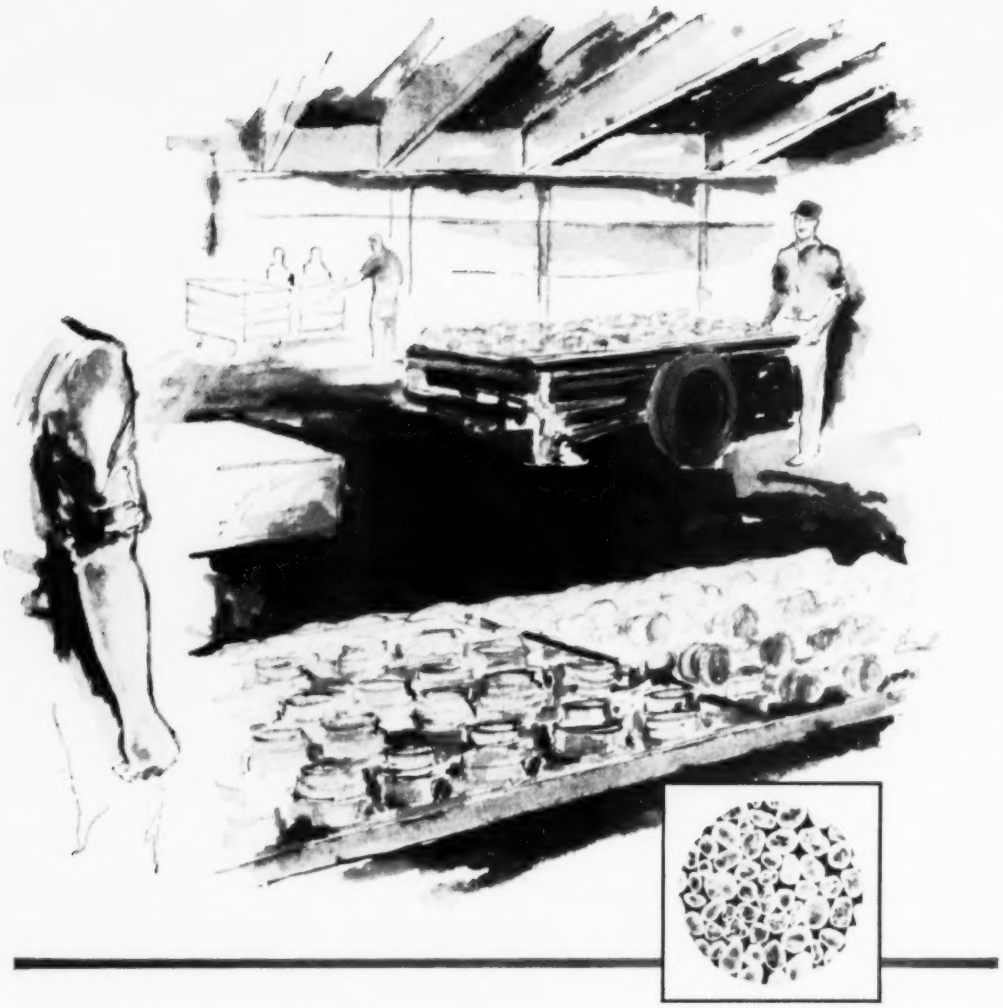

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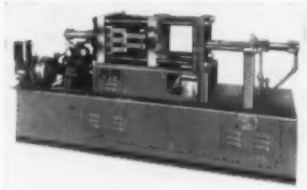
**For Manufacturer's Information Circle No. 1, Page 141-142**

**"TIG" WELDER** . . provides complete, remote, tungsten-inert-gas shielded arc welding facilities in one compact 180-lb. package. *Hobart Brothers Co.*

**For Manufacturer's Information Circle No. 2, Page 141-142**

**LOW COST DIECASTING** . . is principal claim of new 2-1/2 lb capacity, 350 shot per hour, hot chamber die casting



machine. Die thickness 6 in. min; 16 in. max. Locking pressure 150 tons. *American Die Casting Machinery Co.*

**For Manufacturer's Information Circle No. 3, Page 141-142**

**LIQUID ALUMINUM** . . can be cast without heat or pressure. Reportedly hardens within two hours after adding hardener. Castable and bonding material. *Devcon Corp.*

**For Manufacturer's Information Circle No. 4, Page 141-142**

**FILLETING COMPOUND** . . 100 per cent epoxy resin useful in repairing leaks in core boxes, enlarging gates, filling a crack where the gate meets the pattern or for general filleting purposes. *Carl H. Biggs Co.*

**For Manufacturer's Information Circle No. 5, Page 141-142**

**METAL MARKER** . . is ball-point marking tube for permanent coding of castings as well as wood, plastic and glass. Manufacturer states fast-drying ink withstands heat and weathering, and will not chip, peel, fade or rub off under adverse conditions. Available in seven colors. *John P. Nissen, Jr., Co.*

**For Manufacturer's Information Circle No. 6, Page 141-142**

**PLASTIC CORE BOX VENT** . . designed for quick replacement of screen and slotted vents in core boxes and blow plates. Manufacturer states life of plastic vent is up to five times greater than other vents. They can be mounted on vertical walls of core boxes without distorting or restricting removal of cores. *Better Foundry Products.*

**For Manufacturer's Information Circle No. 7, Page 141-142**

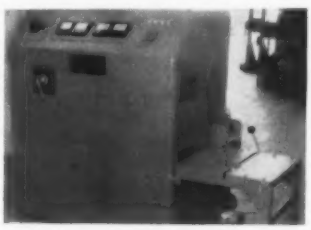
**DEBURRING AND FINISHING** . . tool designed for finishing of protruding radii and convex surfaces of castings. Portable, lightweight belt grinder has three working surfaces, adjustable for large or small radii. *Peterson Tool & Mfg. Corp.*

**For Manufacturer's Information Circle No. 8, Page 141-142**

**PATTERN STORAGE** . . on steel shelving saves space—744 lineal ft of shelving provides 18,000 sq ft. *Penco Metal Products Div., Alan Wood Steel Co.*

**For Manufacturer's Information Circle No. 9, Page 141-142**

**FURNACE MELTING STATION** . . master control station for induction melting furnace includes all components

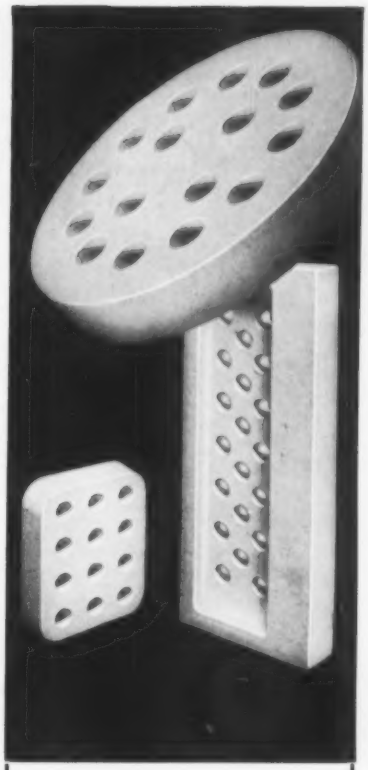


in minimum floor space. Complete for air, vacuum melting. *Ohio Crankshaft Co.*

**For Manufacturer's Information Circle No. 10, Page 141-142**

**INVESTMENT PATTERNS** . . . can be produced from new synthetic, wax-like pattern material. Manufacturer claims uniform quality and physical characteristics produce consistent results. *Pattern*

*Continued on page 10*

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## indoors and outdoors

Most foundries find that smaller "PAYLOADER" tractor-shovels best meet their needs. But in this one a big 4-wheel-drive model is just right. "I couldn't have bought equipment better fitted to the job if I had paid twice as much," says Don LaTulip, the owner.

Four times a day it works indoors scooping up the hot sand, gagger rods and scrap from the pouring floor and dumping it on grizzly bars. Outdoors it picks up and loads out the cupola drops and waste, including 1½ ton slag skulls, also levels the waste dump and does crane and carrying work.

There is a proven size and type in the complete "PAYLOADER" tractor-shovel line that will just fit the tough handling jobs in *your* plant or yard. Carry capacities from 2,000 to 12,000 lbs., plus crane hook, lift forks, pick-up sweeper and snow plow attachments. A Hough Distributor is ready to serve you.

**HOUGH®**

THE FRANK G. HOUGH CO.
LIBERTYVILLE, ILLINOIS
SUBSIDIARY — INTERNATIONAL HARVESTER COMPANY

Send data on the Complete PAYLOADER line and attachments

Name _____
Title _____
Company _____
Street _____
City _____ State _____

MC 5-B-6

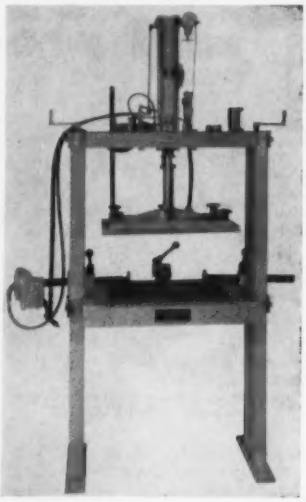
Circle No. 151, Page 141-142


## products and processes

*Continued from page 9*

*Materials Div., J. I. Holcomb Mfg. Co.*
**For Manufacturer's Information Circle No. 11, Page 141-142**

**GLASSED DUCTILE FITTINGS . . .** with strength and thermal shock resistance that exceeds gray iron will be



available July 1. Standard shape fittings will be available in range of sizes. *Pfaudler Co.*
**For Manufacturer's Information Circle No. 12, Page 141-142**

**PORTABLE X-RAY . . .** employs 50-lb generator, is small enough to pass through 6-in. opening, powerful enough to radiograph 1-1/4-in. steel in 45 sec. *Picker X-Ray Corp.*
**For Manufacturer's Information Circle No. 13, Page 141-142**

**LOW HEADROOM HOISTS . . .** are standard in new line of 1-1/2 to 7-1/2 ton capacity units. *Robbins & Myers, Inc.*
**For Manufacturer's Information Circle No. 14, Page 141-142**

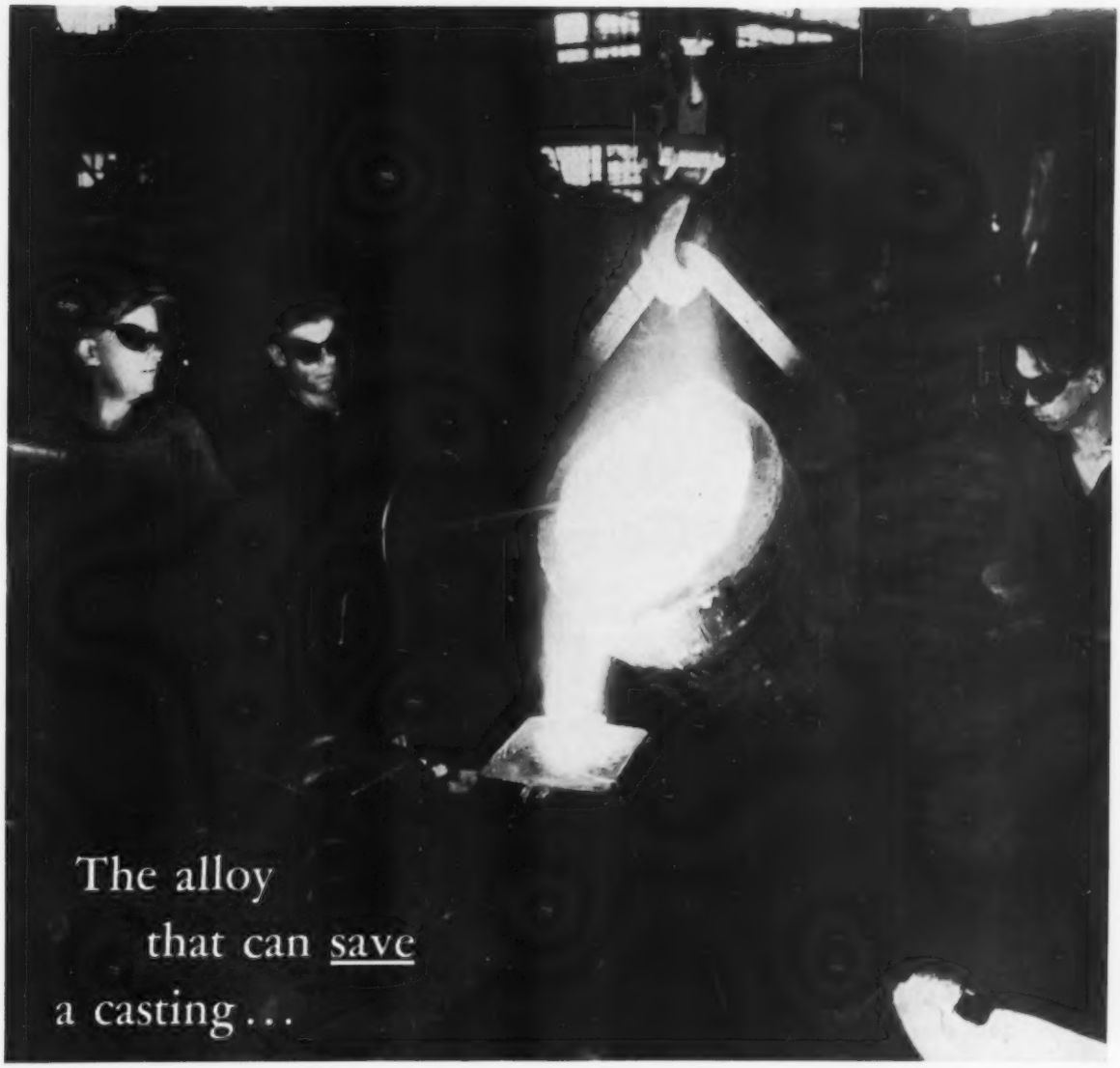
**STICK-SHIFT FORK LIFT . . .** gasoline-engined fork truck with standard transmissions and clutches have been added to line. *Clark Equipment Co.*
**For Manufacturer's Information Circle No. 15, Page 141-142**

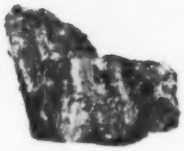
**SAFETY AND STYLE . . .** are provided in new line of safety glasses with frames styled after those provided with prescription types. *Sellstrom Mfg. Co.*
**For Manufacturer's Information Circle No. 16, Page 141-142**

**HOT SUITS . . .** protective clothing is available in duck material with aluminized outer surface, rayon and asbestos backing. *Frommelt Industries.*
**For Manufacturer's Information Circle No. 17, Page 141-142**

**CONTINUOUS CASTING . . .** of aluminum strip is suggested as an auxiliary or side line operation for foundries. Newly developed integrated machine

*Continued on page 18*



**...Vancoram Ferrovanadium!** A small amount of ferrovanadium gives castings extra strength and extra durability. It is one of the most powerful carbide-forming agents you can use—castings resist structural changes even at high temperatures. Ferrovanadium restrains graphitization, too. Graphite flakes are small and uniform in size, thus improving the tensile strength of the metal. Now what about the economics of vanadium? Because you use so *little* to do so *much*, Vancoram Ferrovanadium is far more economical to use than you may realize. And it's plentiful! For more facts about this useful alloy, write us or call any distributor of VCA foundry products. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. • Chicago • Cleveland • Detroit • Pittsburgh

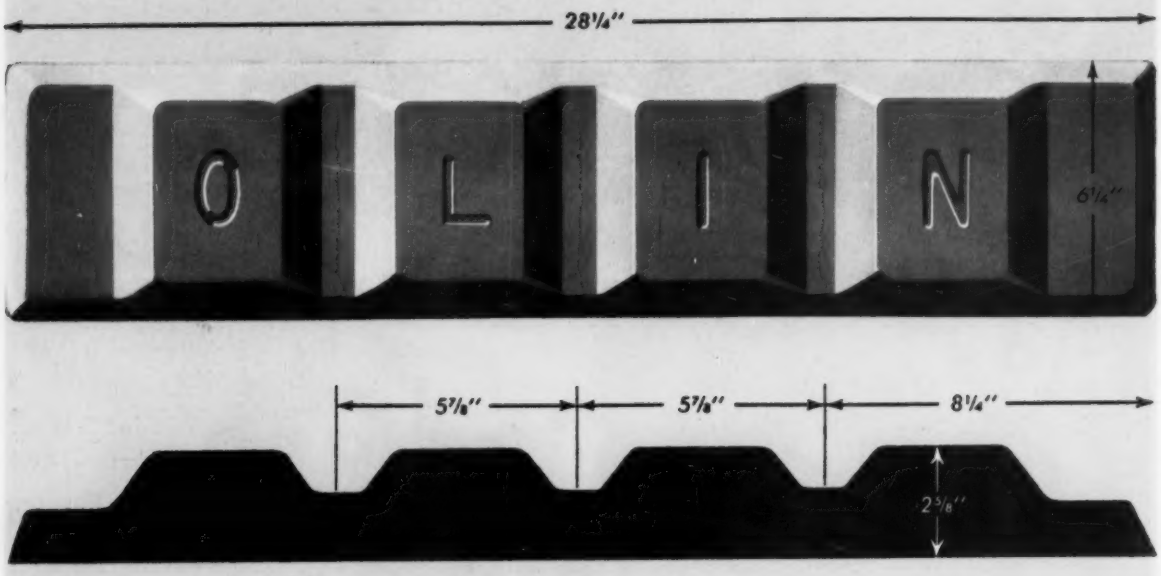
*VCA Iron Foundry Products are also distributed by:* PACIFIC METALS CO., LTD. • STEEL SALES CORPORATION J. M. TULL METAL & SUPPLY CO., INC. • WHITEHEAD METALS, INC. • WILLIAMS & COMPANY, INC.

*Producers of alloys, metals and chemicals*

VANADIUM CORPORATION OF AMERICA

Circle No. 152, Page 141-142

# YOU'LL FIND GOLD
# IN THIS NEW 25 POUND OLIN ALUMINUM INGOT!




**Now, a 25 pound ingot from Olin Aluminum. Consider its advantages for you!**

**Smaller size.** Easier to store, easier to gauge metal supply for closer control.

**Lighter weight.** 25 lbs. vs. 30 lbs. Greatly increases handling efficiency.

**Deeper notches.** Easier to break. Saves time, eases work load.

**More sections.** 3 notches, 4 sections vs. 2 notches, 3 sections. Reduces waste.

**Same price per pound as 30 lb. ingot.** Olin Aluminum is the only prime supplier producing a 25 pound ingot, and at no additional cost.

America's new major aluminum producer, Olin Aluminum, is also the newest source of profitable ideas for foundrymen. Take advantage of it. Contact your nearby Olin Aluminum Sales Office or Authorized Distributor of casting alloys. Ask for our pig and ingot technical data bulletin. Metals Division – Olin Mathieson Chemical Corporation, 400 Park Avenue, New York 22, New York.

OLIN ALUMINUM

*Symbol of New Standards of Quality and Service in the Aluminum Industry*

Circle No. 153, Page 141-142

# With Mogul you can see the difference!

For years, experienced foundrymen have looked to Mogul Cereal Binder to help them consistently turn out top-quality cores. First choice in cereal binders, Mogul gives perfect green bond, offers unusual dependability in spite of usual wide variations in mulling time, types of sand, core shapes and sizes. Mogul provides high green strength; cores hold their shape during handling and storage. They give good collapsibility and easy shake-out, cutting down on strains and hot tears. The excellent permeability of Mogul reduces costly blows due to inadequate venting.

Today, teamed up with Dexocor the *dry* replacement for core oil, Mogul performs better than ever. For outstanding performance on green bond, green sand, for better blowing, easy ramming, easy shake-out, all-around improved handling and more efficient production, the combination of Mogul and Dexocor is unbeatable.

**Your Corn Products technical representative is completely versed in the application of these and other binders and dextrines to mold and core making. Backed by years of experience, a completely equipped foundry laboratory, and the extensive facilities of the world's largest corn processor, our technical representatives will be pleased to work with you to help develop the combination of binders that's right for your needs. Call our nearest sales office or write direct.**

## MOGUL® cereal binder

CORN PRODUCTS SALES COMPANY 17 BATTERY PLACE, NEW YORK 4, N.Y.

Other fine products for the Foundry Industry: DEXOCOR® • KORDEK® binders • GLOBE® dextrines

Circle No. 154, Page 141-142

International Minerals & Chemicals

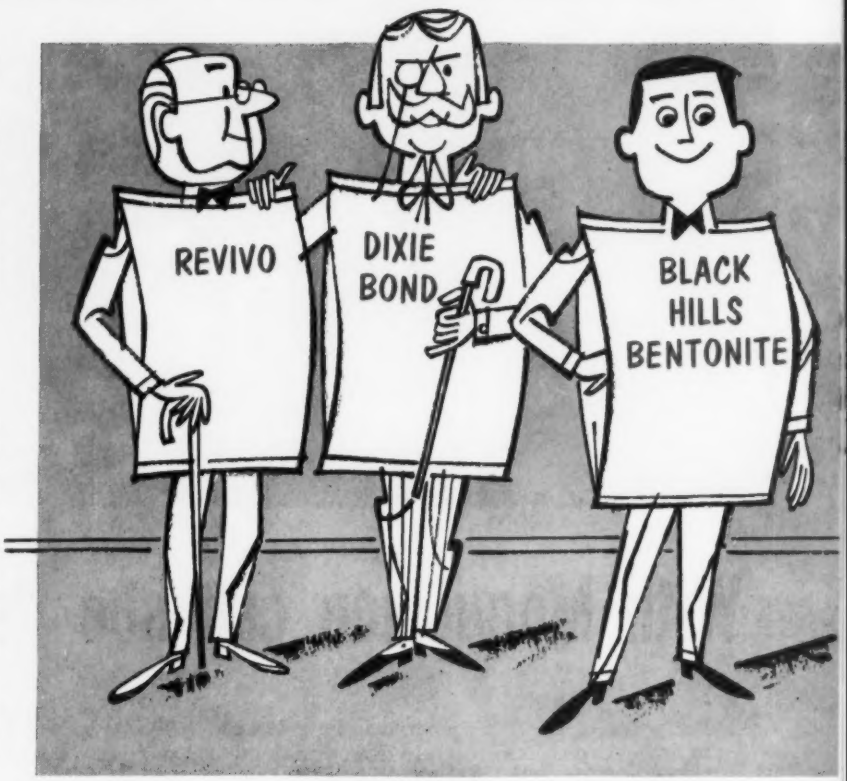
A REPORT TO FOUNDRIES

FROM TOM BARLOW

## The trend in molding:

# accentuate the additives

In green sand molding, progress is more apt to be a matter of evolution than revolution. Changes have been so gradual that we sometimes fail to notice how drastic a difference the last thirty years have made. Did you ever meet and old schoolmate after twenty years and notice how much *he* had changed? In the same way, a Rip Van Winkle of molding would be startled by what he would see today — The Age of Additives.




### Age of Natural Sand

Sand practice has come through at least three distinct phases — with minor but important growths within each period. By-passing ancient history, we can start with the Age of Natural Sand. During this time, the only molding sands were mixtures of sand, clay, silt and miscellany as they occurred in nature. These sands are still used and probably always will be for special applications and/or shops without adequate sand conditioning equipment. They were easy to control because there was nothing *to* control — other than the source from which you bought them.

### Age of Synthetic Sand

The introduction of Revivo (to revive worn-out sand) by ECP was a pioneering move toward the Age of Synthetic Sand. At first, the bonding clays were added to used natural sand (today we call these semi-synthetic). Later foundries started with clean sand and added sea-coal, pitch, etc. Western Bentonite produced somewhat different properties and advanced a little farther from the parent natural-sand values. Lower moisture, high toughness and more permeability became the order of the day. Soon N. J. Dunbeck (of Eastern Clay Products) introduced and patented the use of southern bentonite (known then and now as Dixie Bond). More flowability and permeability with lower hot and dry strengths opened up new possibilities. Today, foundrymen recognize that no one clay can be best for every application. To be impartial in our service and sales work, we produce all three (and some combinations, such as Balanced Revivo).

### Now—the Age of Additives

**We now approach the Age of Additives which probably dates back to ECP's introduction of Westonite, the original waterless molding sand. The purpose of this program was to combine flowability, toughness and strength in the same sand. This cannot be done by clay alone! When synthetic sand was young, many people thought only in terms of one clay—only one way to skin the cat. They now know there are many — each with its own virtues. For example, Dixie Bond is not a direct substitute for Black Hills Bentonite and vice versa. The same philosophy is true of flowability additives. No one can do all jobs equally well. They vary considerably in their effect on green strength, hot strength, dry strength and impact strength.**

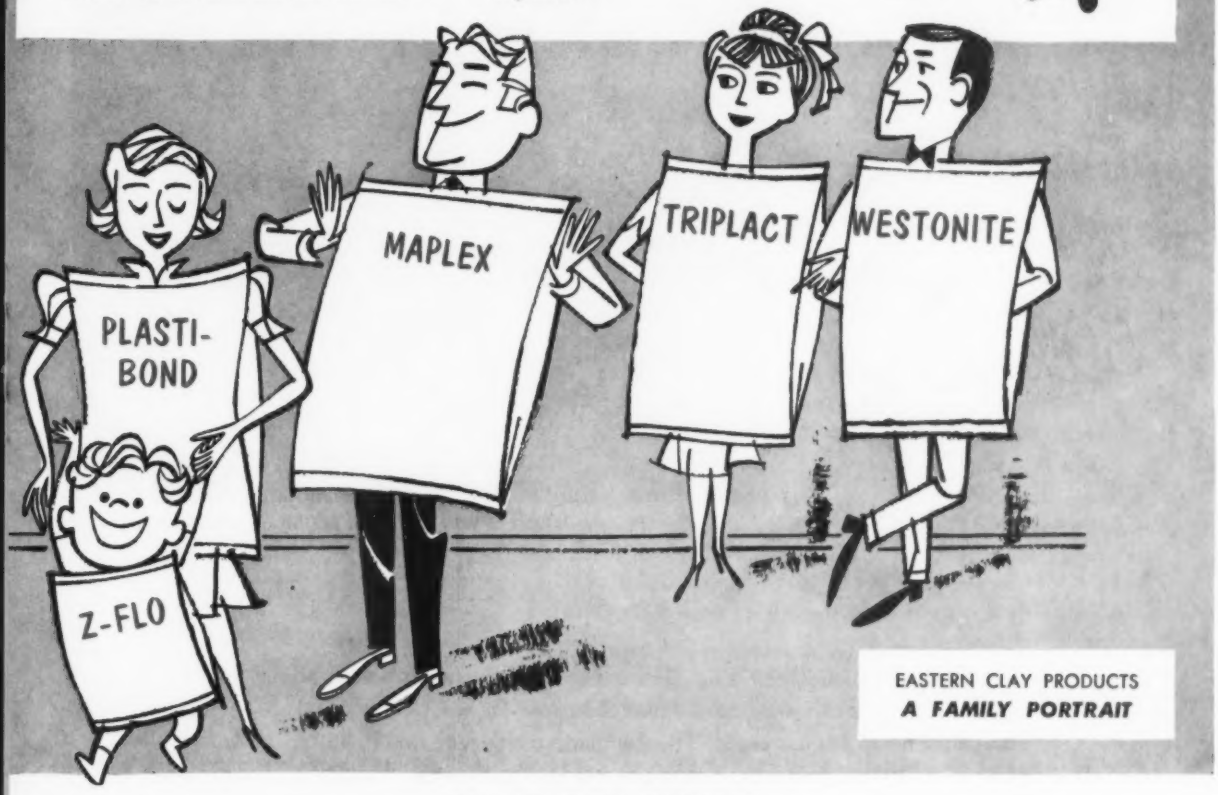
Circle No. 149, Page 141-142

# NEW CHIP OFF THE OLD FAMILY TREE

Have a cigar! There's a new addition to the line of Eastern Clay additives — Z-Flo. Following is a word picture of the type of foundry that might profitably adopt the baby. If one or more of these shoes fit you, why don't we discuss it in person — in detail.

**DO YOU . . .**

- **Require a versatile sand?**
- **Use a slurry system of clay addition?**
- **Have trouble with cuts and washes?**
- **Want a sand that isn't waterproof?**
- **Require a high-durability additive?**
- **Lack adequate mulling time or equipment?**
- **Use either natural or synthetic sand?**
- **Have trouble with deep pockets?**
- **Have broken molds from rough handling?**
- **Use too many facing sands?**
- **Want to use more Dixie to reduce costs and still want good dry strength and toughness?**




EASTERN CLAY PRODUCTS
***A FAMILY PORTRAIT***

In this Age of Additives, there's a *best* additive for what *you* do. We have the entire range to work with and the know-how to make impartial and accurate recommendations. Our research, experience and desire to serve may help you make more money through better castings.

## ALL IN THE FAMILY

Here's a picture of molding progress through the last 20 years. Westonite triggered the Age of Additives. Today — in addition to Maplex (pure hard maple flour) — we insist on producing three distinct grades of additives for better finish, better peel, better casting tolerance and reduced casting defects. In future columns, we will clarify the differences between them, based on both research data and operating experiences. You will have the chance to determine for yourself what member of the Eastern Clay Products family is of greatest interest to you. Don't miss the next exciting episode in the lives of the additive family. The cast includes: TRIPLACT, the oldest; PLASTI-BOND, the most popular; Z-FLO, baby of the family.

International Minerals & Chemicals

Creators of
Living Minerals

EASTERN CLAY PRODUCTS DEPT.

**INTERNATIONAL MINERALS & CHEMICAL CORPORATION**

Administrative Center, Old Orchard Road, Skokie, Illinois • ORchard 6-3000

1-59

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# WITH TAYLOR ZIRCON RAMMING MIX

*Mould Manufacturer cuts induction furnace lining costs by*

*50%*

Pouring a heat of grey iron from 650 lb. high frequency induction furnace lined with TAYLOR ZIRCON No. 717 Ramming Mix.

TAYLOR ZIRCON No. 717 Ramming Mix has cut refractory lining costs *in half* for a mid-west mould manufacturer. In addition, average number of heats has increased. This company melts grey iron in 650 lb. and 1000 lb. induction furnaces to produce moulds for the glass industry.

Alert foundries are standardizing on TAYLOR ZIRCON Ramming Mix as the most economical lining for high frequency furnaces. High softening point, low thermal conductivity, high di-electric strength, and volume stability make TAYLOR ZIRCON an excellent refractory for this service. For detailed information, write direct, or call in a Taylor field engineer.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

The CHAS. TAYLOR SONS Co.
A SUBSIDIARY OF NATIONAL LEAD COMPANY
REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U.S.A.

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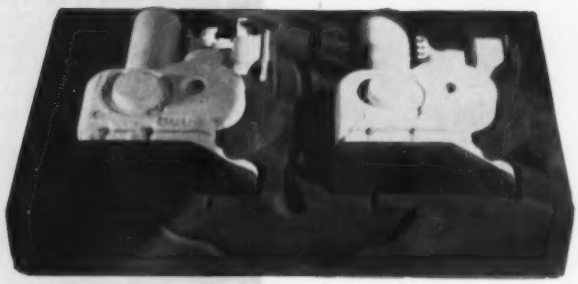
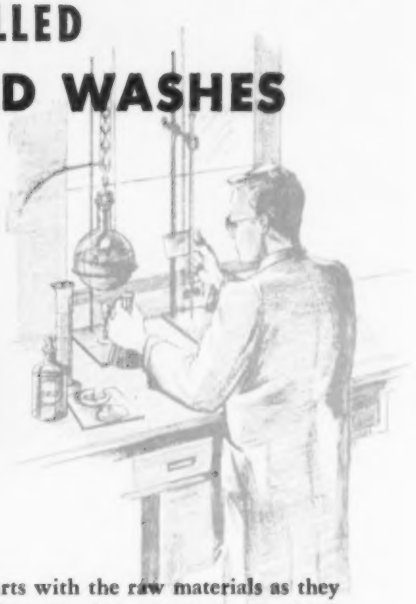
# CONTROLLED QUALITY CASTING FINISH

## BEGINS WITH

## QUALITY CONTROLLED

# DELTA CORE AND MOLD WASHES





**DELTA FOUNDRY PRODUCTS**

•

**CORE AND MOLD WASHES**
Plastic-type and powder-type for steel, malleable, gray iron and non-ferrous castings.

•

**PARTINGS**
Powder Type, Liquid Type, Concentrate.

•

**SPECIFICATION CORE OILS**
to meet every core making and baking requirement.

•

**CORE RESINS**

•

**CORE BINDERS**

•

**SILICATE-COLD PROCESS BINDERS**

•

**MOLD SPRAY BINDERS**

•

**MUDDING AND PATCHING COMPOUNDS**

•

**MILL COATINGS**

•

**SPECIALTY PRODUCTS**
Chill Oil • Sand Conditioning Oil • Sand Release Agent • Permi-Bond • Core Adhesives • No-Vein Compound • Mold Seal Compounds • and many others.

Quality control, at Delta, starts with the raw materials as they are received at the plant. Before permission is given to unload, samples are sent to the laboratory for approval.

Intervals and techniques of sampling are important in both raw materials and manufacturing processes. Any deviation from approved methods could confuse the most exacting quality control operation.

Means and mechanisms for the operation and regulation of equipment . . . for the control of time and temperature factors . . . are often critical considerations in the control of product quality. Variations are restricted to prescribed tolerances which are constantly supervised by quality control personnel.

Delta's control of product quality is the user's assurance of product uniformity. And the product uniformity of Delta Products is a critical factor in the quality control of casting finish.

**TEAMWORK . . . IN FOUNDRY SCIENCE AND CHEMICAL RESEARCH**

OUR 26TH YEAR

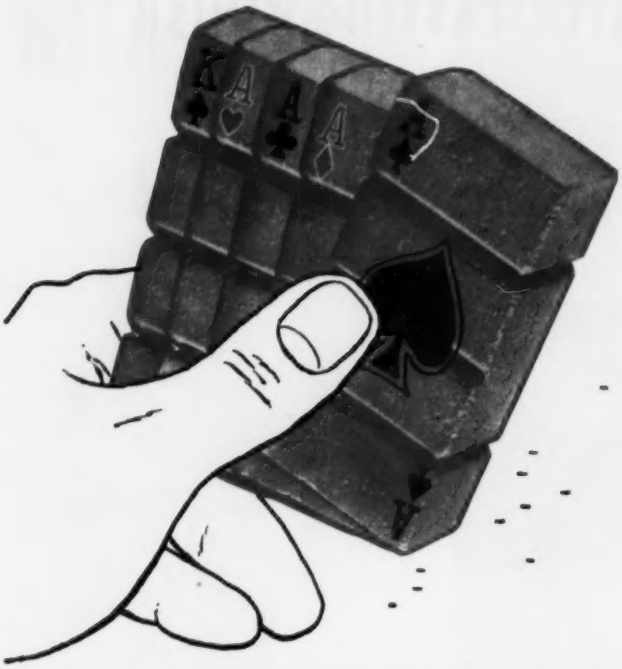
**DELTA**

*Get the facts . . . Working samples and complete literature on Delta Foundry Products will be sent to you on request for test purposes in your own foundry.*

**DELTA OIL PRODUCTS CORP.** | **MILWAUKEE 9, WISCONSIN**

**MANUFACTURERS OF SCIENTIFICALLY CONTROLLED FOUNDRY PRODUCTS**

Circle No. 158, Page 141-142



# Don't Gamble with Iron Quality

use *Famous*

## CORNELL CUPOLA FLUX

### for Gray Iron and Malleable Foundries

**USE FAMOUS CORNELL CUPOLA FLUX with each ton charge of iron. Your iron will be cleaner. Your scrap losses will be less. You'll get greater tensiles and the increased lining life both in cupola and ladles will save you money in manpower and materials. Why not call a Cornell Flux engineer today and assure yourself of cleaner iron every time.**

*P.S. If you melt aluminum, copper or brass, try Famous Cornell Aluminum, Copper or Brass Flux.*

*Write for Bulletin 46-A.*

*don't accept substitutes*

FAMOUS CORNELL FLUXES

## The CLEVELAND FLUX Company

**1026-40 MAIN AVENUE, N.W. • CLEVELAND 13, OHIO**

*Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918*

Circle No. 159, Page 141-142


## products and processes

*Continued from page 10*

is said to produce 4 tons of 1/8-in. strip hourly. *Lobeck Casting Processes Inc.*

**For Manufacturer's Information Circle No. 18, Page 141-142**

**MOLD SHOOTER** . . unit for producing stack molds has built-in $CO_2$ gasser. Single master control shoots mold, gasses, strips, and reloads machine with sand. *Hansberg Shooters Inc.*

**For Manufacturer's Information Circle No. 19, Page 141-142**

**DUCTILE IRON** . . is produced more efficiently with alloy 55, a new high-magnesium silicon-base composition. Suitable for use in plunging technique. *Union Carbide Metals Co.*

**For Manufacturer's Information Circle No. 20, Page 141-142**

**HEAT SHIELD** . . Pyrex glass shield reflects heat to provide comfort for workers near melting, heat treating or baking operations. *Corrning Glass Works.*

**For Manufacturer's Information Circle No. 21, Page 141-142**

**SHELL CORE BOXES** . . . are available cast-to-size by Shaw Process. Ledges on boxes permit use of inexpensive clamps. *Wisconsin Pattern Works.*

**For Manufacturer's Information Circle No. 22, Page 141-142**

**STAINLESS ALLOYS** . . in new group of molybdenum-containing alloys of 18-8 type, and designated as PH55 series, are planned to meet requirements for high strength and hardness with greater corrosion resistance. *Cooper Alloy Corp.*

**For Manufacturer's Information Circle No. 23, Page 141-142**

**CAR SHAKER** . . for unloading covered railroad hopper cars cuts handling time. *National Air Vibrator Co.*

**For Manufacturer's Information Circle No. 24, Page 141-142**

**POLYESTER RESINS** . . for fabricating plastic parts by hand lay-up are available in new line. *Interchemical Corp.*

**For Manufacturer's Information Circle No. 25, Page 141-142**

**ELECTRIC TRUCKS** . . for use in crowded quarters available in 2000-lb and 3000-lb capacity models. *Elwell-Parker Electric Co.*

**For Manufacturer's Information Circle No. 26, Page 141-142**

**$CO_2$ GASSER** . . . pressure gassing machine features 25 x 30-in. conveyorized table and cast spacers for quick vertical height adjustment, 20 x 24-in. gassing head and timing controls *Alphaco, Inc.*

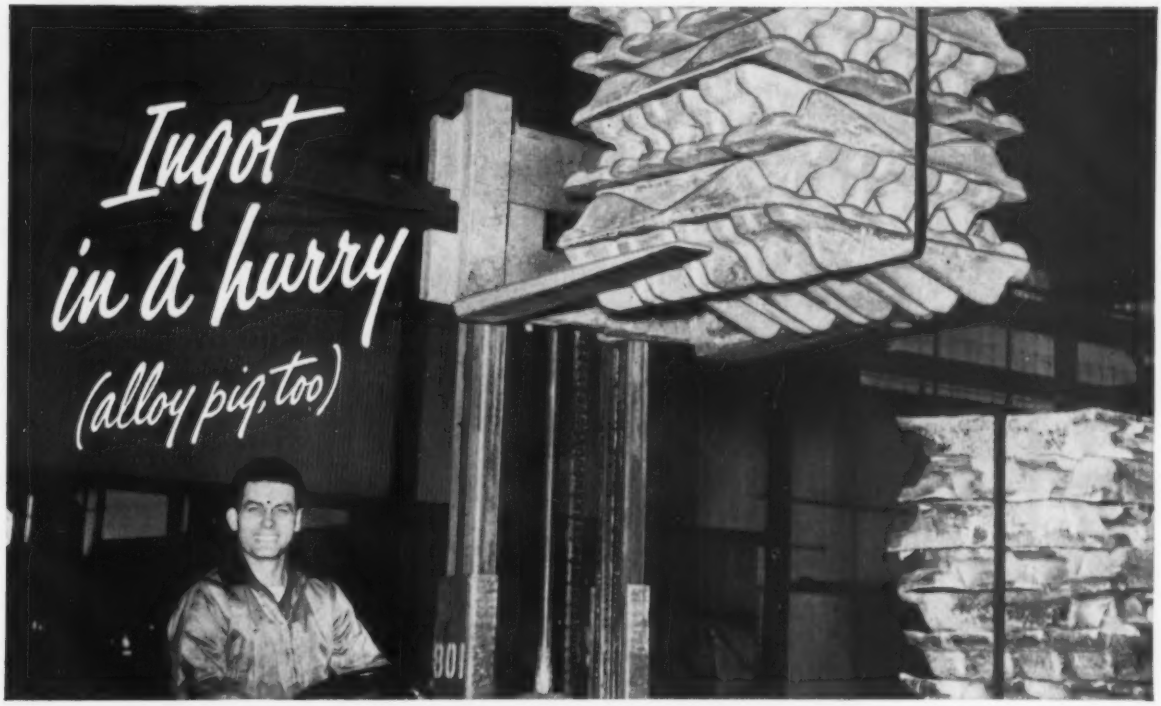
**For Manufacturer's Information Circle No. 27, Page 141-142**

**METALLURGICAL MICROSCOPES** . . . for quick, accurate routine examination of metal specimens are available in new, low-cost line. *Bausch & Lomb Optical Co.*

**For Manufacturer's Information Circle No. 28, Page 141-142**

**LARGE DIE CASTINGS** . . . such as

*Continued on page 20*




# ...get fast delivery on any aluminum alloy pig or ingot from your REYNOLDS INGOT DISTRIBUTOR

The old cliche, "time is money" really hits home when your casting operation is held up for want of metal. But if that metal is aluminum, there's no problem. Just call your local Reynolds Ingot Distributor.

Chances are, the metal you need—in the right alloy and size will be at your doorstep in 24 hours or less from your Reynolds Distributor's stock. Or he can get you any casting alloy for prompt shipment from Reynolds plant inventory.

Your Reynolds Ingot Distributor is geared to deliver the pig and ingot you need *fast*. Call him.

***REYNOLDS INGOT DISTRIBUTORS***

**Abasco, Incorporated,** P. O. Box 13367, Dallas 20, Texas • **American Alloys Corp.,** 4446 Belleview, Kansas City, Mo.
**Atlas Metal Co.,** 8550 Aetna Road, Cleveland 4, Ohio • **Barth Smelting Corp.,** 99-129 Chapel Street, Newark, N. J.
**Bay State Refining Co.,** 8 Montgomery Street, Chicopee Falls, Mass. • **Milward Alloys, Inc.,** Lockport, N. Y.
**Morris P. Kirk & Son, Inc.,** 2700 S. Indiana St., Los Angeles, Calif. • **Richards Corporation,** 356 Commercial St., Malden, Mass.
**Sipi Metals Co.,** 1720 N. Elston Ave., Chicago 22, Ill. • **Sonken-Galamba Corporation,** 2nd and Riverview, Kansas City, Kansas
**Nathan Trotter & Co.,** 36 N. Front Street, Philadelphia, Pa.

Watch Reynolds TV show—**"WALT DISNEY PRESENTS"**—every week on **ABC-TV**

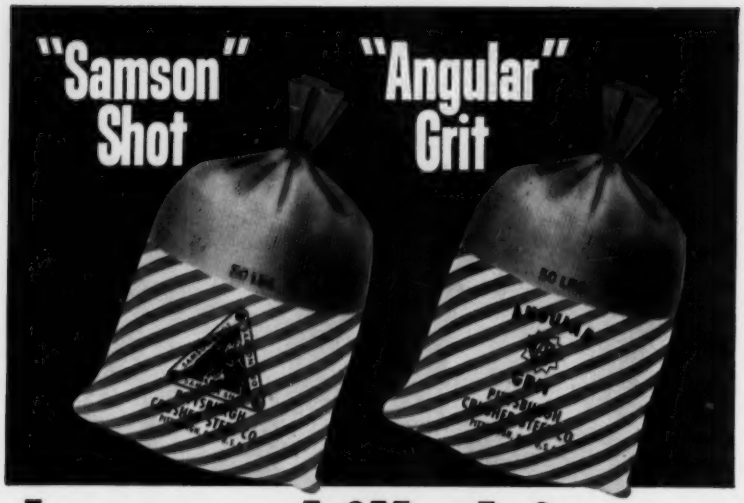
The Finest Products Made with Aluminum are made with REYNOLDS ALUMINUM

*WRITE FOR FREE CHART OF REYNOLDS CASTING ALLOYS* →

**Reynolds Metals Company**
**Box 2346FL-6, Richmond 18, Virginia**
Please send me your free chart listing available Reynolds Aluminum Casting Alloys

*Name* _____
*Company* _____
*Address* _____
*City* _____ *Zone* ____ *State* _____

**Circle No. 160, Page 141-142**




# better chilled iron abrasives..and why

We have made metal abrasives since 1888. We pioneered their use in place of silica sand for blast-cleaning. We have "grown up" with their expanding use, acquiring unequalled know-how and experience along the way. *No other maker of metal abrasives has an equal experience record.*

Since 1937 we have carried on a continuous program of research for improvement of metal abrasives with one of America's foremost metals research organizations. *No other metal abrasives maker has an equal record of research.*

Ours is the only plant in America using the HOT BLAST MELTING process for production of metal abrasives; this, plus fully automated processing, provides the complete quality control that assures uniformity of chemistry, structure and hardness from one lot to another —assures the user of obtaining the same high performance from every shipment of Samson Shot and Angular Grit.

Experience, research, superior manufacturing facilities make these better chilled iron abrasives cheaper to use than those made to sell at a price.

**LEADERS in development of PREMIUM-TYPE ABRASIVES**

The two best known names in premium abrasives were developments of two of our subsidiaries. MALLEABRASIVE, the first malleablized type of metal abrasive ever produced, set the pace for development of all other makes of premium abrasives. TRU-STEEL Shot was the first high-carbon all steel shot produced to meet demand for this specialized type of abrasive.

*One of these products may do your blast-cleaning job better, and at lower cost. Write us for full information.*

## PITTSBURGH CRUSHED STEEL CO.

Arsenal Sta., Pittsburgh 1, Pa.

*Subsidiaries:* The Globe Steel Abrasive Co., Mansfield, Ohio (Malleabrasive)
Steel Shot Producers, Inc., Arsenal Sta., Pittsburgh (Tru-Steel)

Circle No. 161, Page 141-142




*Continued from page 18*

meter and lamp housings and outboard engine blocks can be produced in new 1000-ton die casting machine. *Lester-Phoenix, Inc.*

**For Manufacturer's Information Circle No. 29, Page 141-142**

**NEW FERROCHROME** . . . high-silicon refined chrome is claimed by producer to provide lowest cost chromium and silicon for either cupola or ladle additions to cast iron. *Union Carbide Metals Co.*

**For Manufacturer's Information Circle No. 30, Page 141-142**

**dive deep**

into the information available by circling numbers on card, last page, and you'll be amazed at what you come up with.

**INGOTS IN TAILORED COVERS** . . . bundles of aluminum and alloy ingots are being shipped in plastic covers to protect the ingots from weather and grease. *Rother Smelting Co.*

**For Manufacturer's Information Circle No. 31, Page 141-142**

**AUTOMATED BLAST CLEANING** . . . is available in system employing 12-ft tumbling barrels that are loaded, operated and unloaded by automatic control sequence. *Pangborn Corp.*

**For Manufacturer's Information Circle No. 32, Page 141-142**

**DROP STAMP** . . . straightens malleable castings warped during anneal. Air-operated unit features simplified tooling set-up permitting application to short-run production. *Chambersburg Engineering Co.*

**For Manufacturer's Information Circle No. 33, Page 141-142**

**LADLE NOZZLES** . . pressure-impregnated with coal tar pitch are said to provide production economies and an improved end product. *Wood Preserving Div., Koppers Co.*

**For Manufacturer's Information Circle No. 34, Page 141-142**

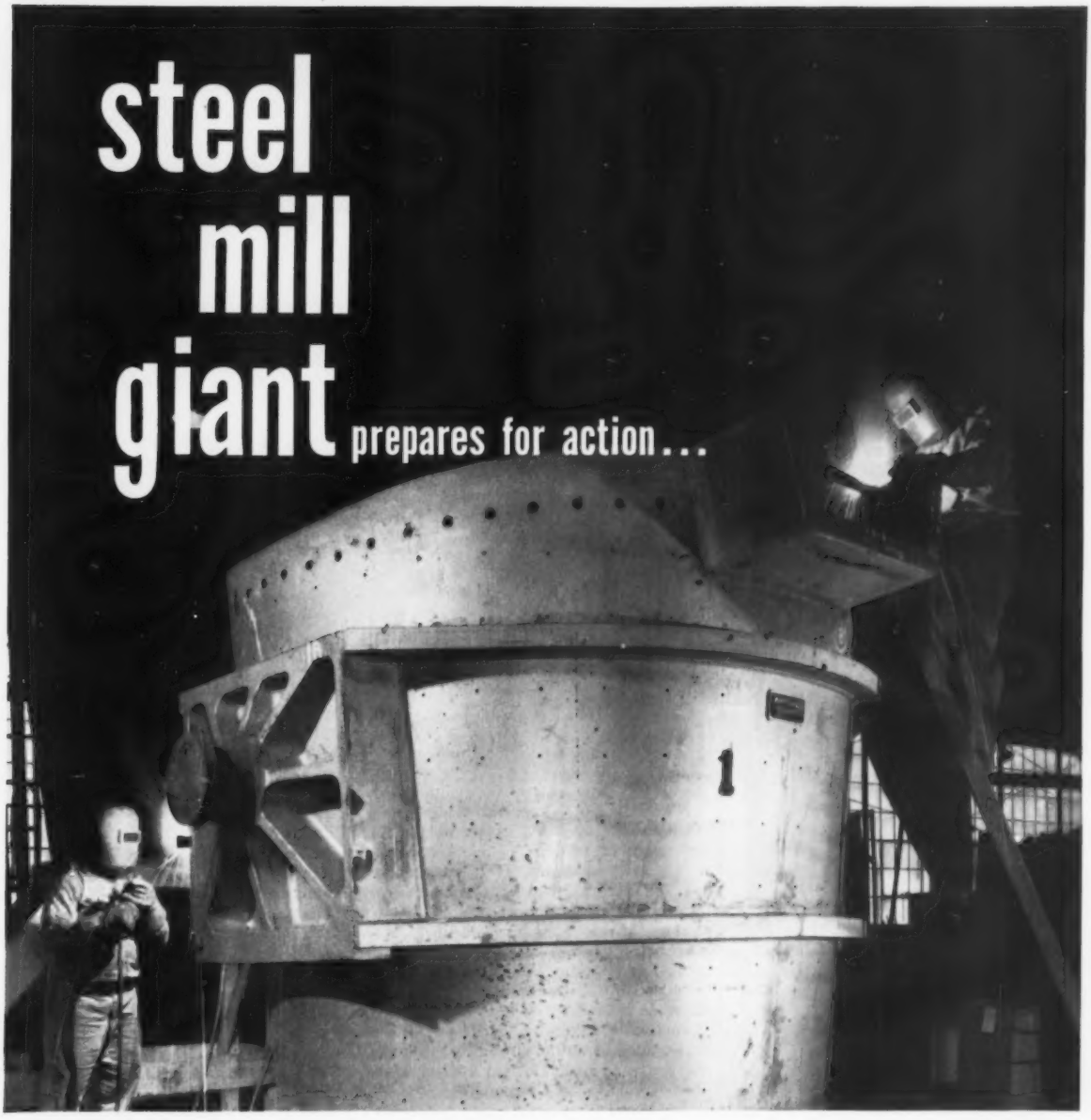
**PLASTIC RUBBER** . . new material for pattern and core box manufacture or repair has been developed. Resists abrasion and erosion. Suitable for other foundry applications. *Dike-O-Seal Inc.*

**For Manufacturer's Information Circle No. 35, Page 141-142**

**MONITOR CONTROL** . . is available for automatic foundry machinery. Unit tells maintenance men where to find trouble when automated machine stops at any point in cycle. *Gemco Electric Co.*

**For Manufacturer's Information Circle No. 36, Page 141-142**

# steel mill giant prepares for action...



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Circle No. 162, Page 141-142

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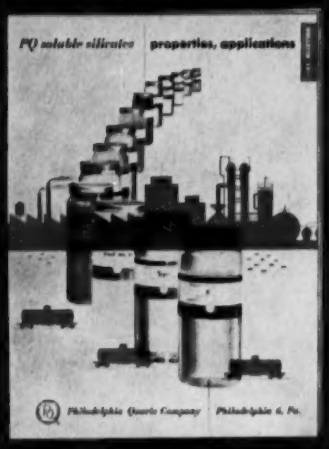


This bulletin puts valuable facts about sodium and potassium silicates at your finger tips. It reviews the physical and chemical properties of PQ Silicates that are useful in various industrial processes.

Uses for sodium silicates which may have special interest for you . . . sealants for porous castings • binders for cements, foundry molds • detergents for cleaning metals • coagulant aids in water treatment.

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Circle No. 163, Page 141-142


# let's get personal

**James H. Smith** . . . general manager, Central Foundry Div., GMC, since 1946 on May 1 assumed supervision of the consolidated activities of Central Foundry Division and Fabricast Divisions of General Motors Corp. Fabricast is now a part of the Central Foundry Division, and its two plants in Bedford, Ind., and Jones Mills, Ark., are now designated as Fabricast plants of the Central Foundry Division.

**George T. Dupre** . . . associated with National Engineering Co., Chicago, since 1950, latterly as assistant to the president, has been named as midwest district sales manager.

**William A. Mader** . . . has been named vice-president, Oberdorfer Foundries, Inc., Syracuse, N. Y., heading up the newly established Technical Service Division, which combines the quality, service and laboratory control departments. Mader, associated with Oberdorfer for 16 years in various technical and administrative positions, is a member of the AFS Central New York Chapter.

**Harry C. Ahl** . . . is now manager, castings sales, Custom Castings Div., Malleable Iron Fittings Co., Branford, Conn.

**Kurt A. Miericke** . . . is technical representative of foundries for Baroid Chemicals, Inc., Houston, Texas, a subsidiary of National Lead Co. He will continue to headquarter in Chicago.

**Alexander Szabo** . . . with Pangborn Corp., Hagerstown, Md., since 1955, is now an abrasive engineer. **Robert D. Rose**, formerly with Industrial Metal Abrasive Co., has also been named abrasive engineer. Both will headquarter in Chicago.

**Harold F. Schulte** . . . with Wheelabrator Corp., Mishawaka, Ind., since 1940 and acting chief engineer since April, 1958, has been named chief engineer.

**Harold R. Warsmith** . . . formerly general superintendent, Jeffrey Mfg. Co., Columbus, Ohio, has been named factory manager. **John R. Simon**, formerly machine division superintendent, succeeds Warsmith.

**L. B. Polen** . . . formerly Buffalo plant manager, Allegheny Ludlum Steel Corp., is now manager of manufacturing for the company's Forging and Castings Division which has been expanded to include the Buffalo foundry. He will direct production operations at both the Buffalo, N. Y. and Ferndale, Mich., plants of the division. Polen is Chairman of the AFS Western New York Chapter.

**S. Pasick** . . . is now sales and service engineer, Battle Creek Foundry Co., Battle Creek, Mich. He was formerly associated with Albion Malleable Iron Co. Albion, Mich., and Sterling National Industries, Milwaukee. Pasick is vice-chairman, AFS Central Michigan Chapter, and was formerly director of the AFS Detroit Chapter.

**Lewis H. Gross** . . . formerly chief chemist and metallurgist with American-Standard Radiator & Sanitary Corp., has been appointed to the faculty of Mergenthaler Vocational Technical High School, Baltimore, Md., where he teaches metallurgy and foundry practices. He has been active in the Chesapeake Chapter, serving as chairman 1956-57, and was instrumental in developing the new school laboratories when constructed in 1953.

**Harry E. Gravlin, Jr.** . . . formerly assistant general manager, parts and equipment manufacturing division, Chrysler

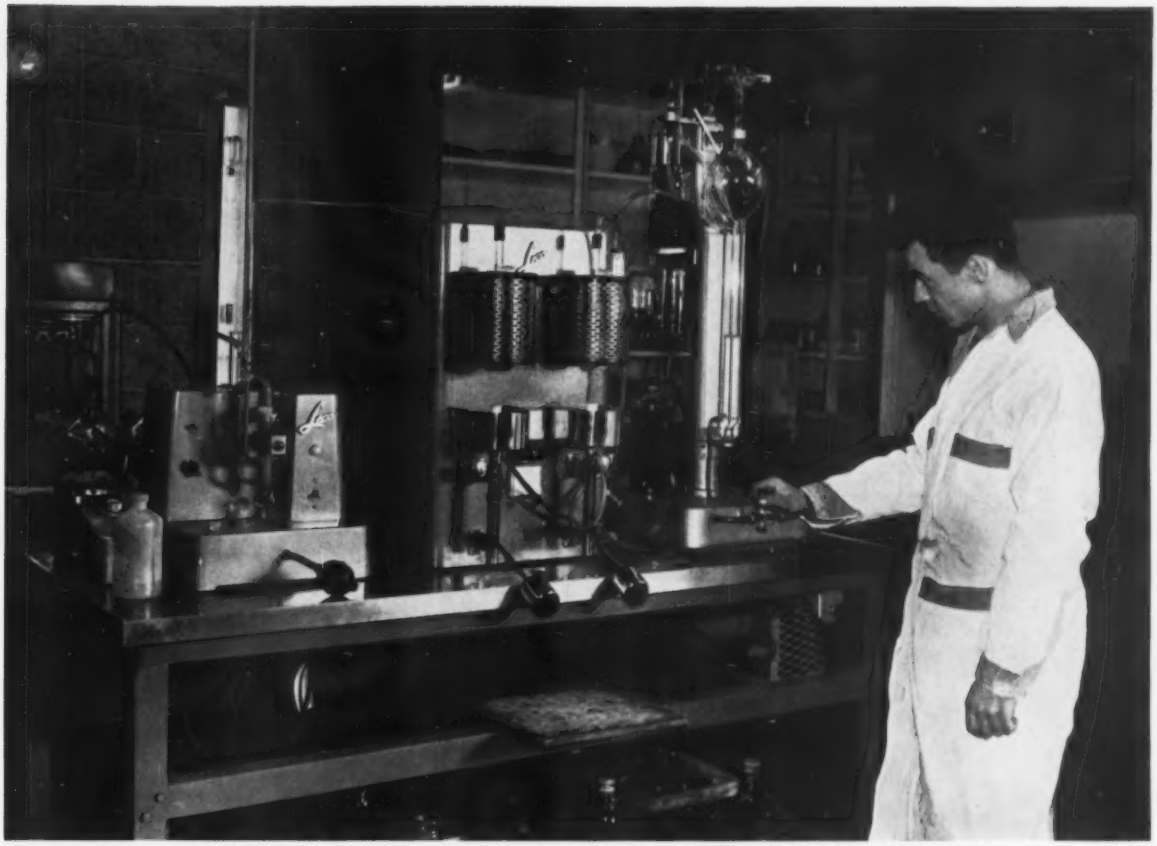
*Continued on page 116*

J. H. Smith

A. J. Szabo

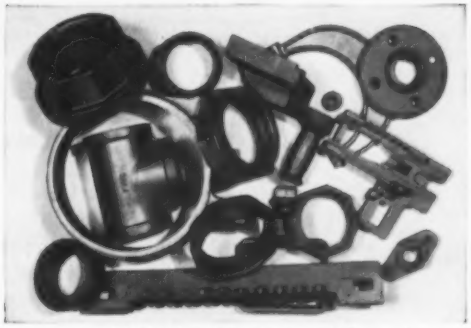
H. F. Schulte

H. R. Warsmith



*This completely equipped testing laboratory maintains a close watch over all New England Malleable production.*

# New England Malleable maintains high standards with HANNA PIG IRON



*Machining is kept to a minimum by precision casting at New England Malleable.*

Weighing from less than an ounce to more than ten pounds, the wide range of pipe fittings and other castings produced at New England Malleable Iron Company have one thing in common. They are all fine grain, close tolerance pieces that require a minimum of machining.

This completely mechanized plant at Warwick, Rhode Island, helps assure its high standards with both Hanna malleable and Silvery pig iron. And it checks these standards almost continuously in a complete chemical and physical laboratory which makes hourly tests of the melt, and delivers reports in 30 minutes.

New England Malleable, like many other Hanna customers, counts on the *high metallurgical quality* of Hanna pig irons for the production of denser, stronger castings with *constant* machining characteristics. These features are particularly true of HANNATITE®, a special iron possessing extra-fine grain structure with smaller, uniformly distributed graphite flakes.

Whatever you cast, large or small, there's a Hanna pig iron to do the job best. All regular grades, plus HANNATITE® and Hanna Silvery, are available in the regular 38-lb. pig or the new 12½-lb. pig. For the iron to suit your particular needs, call a trained Hanna representative for assistance.

**THE HANNA FURNACE CORPORATION**
Buffalo • Detroit • New York • Philadelphia
Merchant Pig Iron Division of
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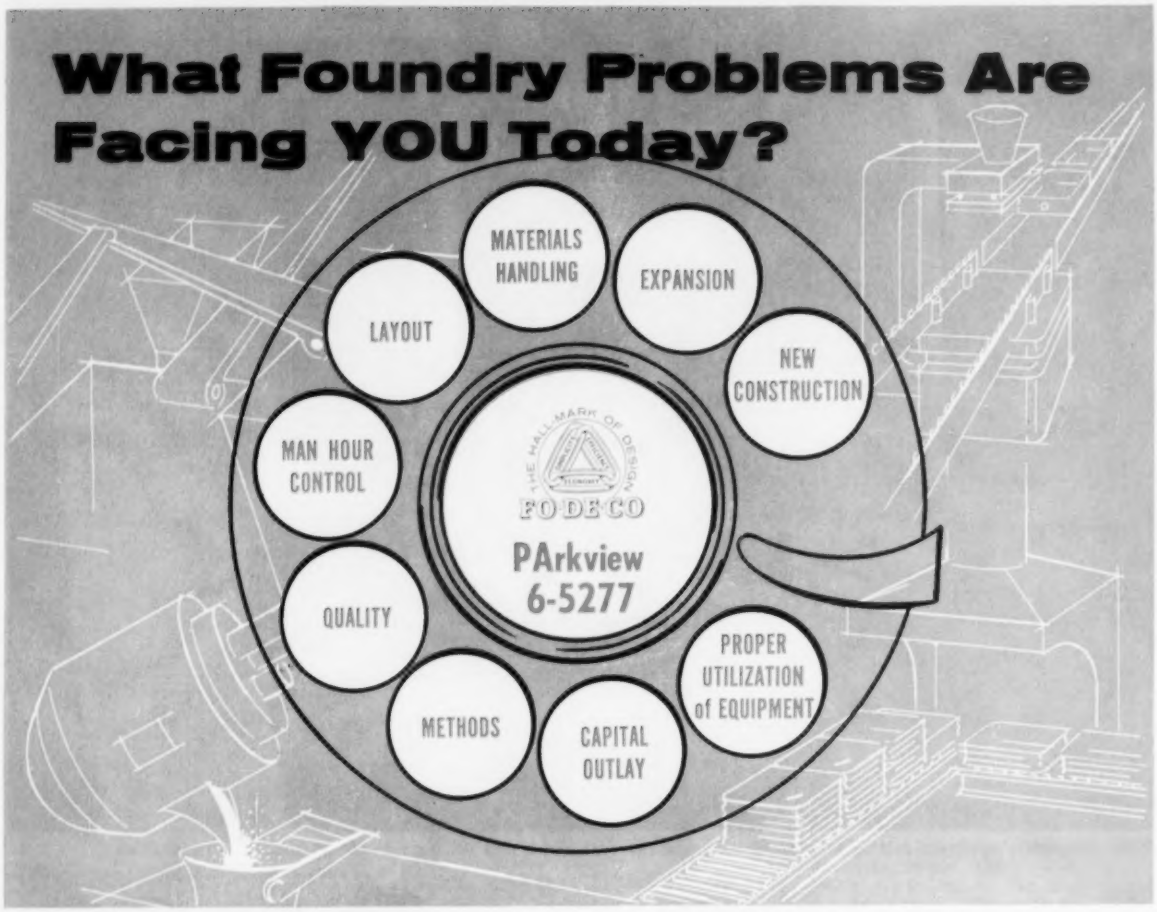
Circle No. 164, Page 141-142

# What Foundry Problems Are Facing YOU Today?

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| MACK TRUCKS, INC. (Steel Foundry), | New Brunswick, N. J. |
| OTIS ELEVATOR CO. | Yonkers, N. Y. |
| A. P. SMITH MANUFACTURING CO. | East Orange, N. J. |
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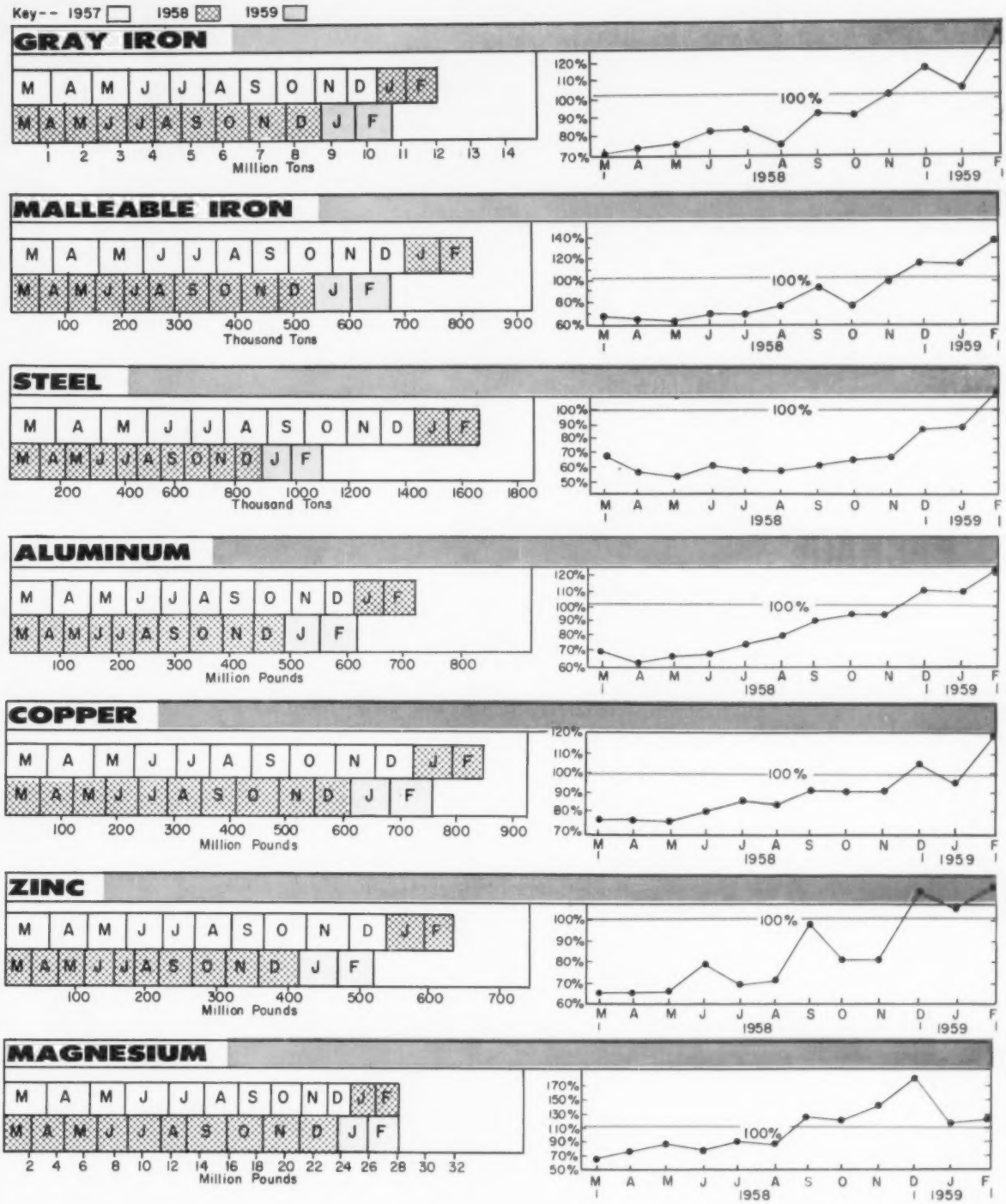
Circle No. 165, Page 141-142

# how's business . . .

Business in the metalcasting industry is certainly picking-up. By using statistics provided by the Bureau of Census, Department of Commerce, Modern Castings has prepared this special comparison of month-to-month metalcasting shipments for the years 1957, '58 and '59. On the left, horizontal bar charts give a direct comparison of each month for the two year period March 1957 through February 1959 and the accumulative total for the two years.

The right-hand set of graphs demonstrate the steady upswing of business during the last half of 1958 and continuing into 1959. Shipments for each of the last 12 months are compared with the corresponding month a year previously and the ratio converted to per cent. For example, gray iron shipments were 1,133,000 tons in March, 1957, and 796,000 tons in March, 1958, or about 70 per cent of the 1957 rate. So the curve starts at 70 per cent for March, 1958, and climbs to 138 per cent for February, 1959, when shipments of 1,037,000 tons exceeded by far the 753,000 tons shipped in February, 1958.



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## NEW TECHNIQUE!

In plunging, a refractory basket containing the magnesium additive is plunged into an already filled ladle of iron. Flame and smoke are virtually eliminated. Slag volume is significantly reduced. Magnesium recovery is more consistent. SAVINGS OF UP TO 50% OF ALLOY COSTS ARE BEING REGULARLY OBTAINED.

## SPECIAL PACKAGE

If the plunging technique fits your operation, you will be interested in Ohio Ferro-Alloys' special alloy package developed specifically for this technique. Our Sil-Mag alloys are now available in cans containing the exact weight required for specific ladle treatments. The package is designed for insertion directly in the plunger. Possible alloy losses in handling and weighing operations are eliminated.

MAXIMUM CONVENIENCE — MINIMUM COST . . .

Write for your copy of our new brochure, "Plunging Sil-Mag Alloys."

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Circle No. 144, Page 141-142

ANOTHER ADVANTAGE: Pallets holding sixty cans for convenient handling and storage.

# Radioactive COBALT-60

## The Pill for Industrial Headaches

MAURICE DALY
*Canadian Steel Foundries (1956) Ltd.*
*Montreal, Que.*

A small pill of radioactive cobalt 60 can be a powerful atomic camera capable of revealing the innermost secret ailments afflicting your castings.

Inspection of steel castings with radioactive cobalt 60 has been satisfactorily employed for quality control at Canadian Steel Foundries for over five years. Although radiography with cobalt 60 is relatively new, radiography using radium dates back a good number of years. With many different isotopes now available, proper use requires a degree of proficiency in physics, mathematics and chemistry.

### REQUIREMENTS

To qualify as an isotope radiographer, one must be trained in the following subjects:

- Safety principles
- Radiographic techniques
- Metal fabrication methods
- Fundamentals of metallurgy.

This can only be achieved through education and practical experience.

### COBALT 60

Cobalt is an artificially produced radioactive isotope. It is made by placing the "target," cobalt metal, into an atomic pile and irradiating it for a period of time. As the target absorbs neutrons, it immediately becomes unstable, emitting useful and/or harmful gamma rays. These invisible rays are useful if employed in such fields as cancer therapy, gaging, industrial radiography, etc. With these gamma rays one can inspect the "inside" of a casting to determine its soundness or unsoundness.

Gamma rays can harm the human body and care should be taken to prevent the body from re-

**CANADIAN PRIZE PAPER**

**This article was a prize-winning entry for 1958 in the annual technical paper contest sponsored by the AFS Eastern Canada Chapter.**

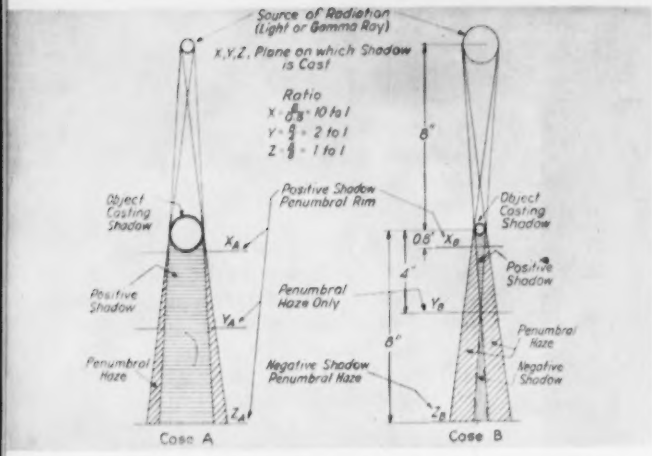



**Fig. 2 . .** Shadow formation: Case A, source of radiation smaller than object casting shadow; Case B, source larger than object casting shadow.

ceiving excessive amounts of radiation. If the individual exercises proper care and remains aware of the safety principles, the element of danger can be eliminated.

The characteristics of cobalt 60 isotope are shown in Table 1.

## PROCEDURE

Radiographic technique requires the placement of a sensitized film immediately behind a casting or section of a casting. The film in turn is sandwiched between shields slipped into a cassette. The radioactive "pill" of cobalt 60 is placed at a predetermined distance facing the casting. Part of the gamma rays emanating from the isotope will penetrate the casting and part will be absorbed.

The amount absorbed will depend upon the thickness of the material and its density. Thick sections absorb more of the radiation than thin ones. The radiation passing through the casting impinges on the film in the cassette. The greater the amount of radiation reaching the film, the darker will be the resultant image. Voids or thin areas will stand out in contrast against the surrounding homogeneous metal.

**Fig. 3 . .** Group of casting arranged around a single source to be radiographed simultaneously.

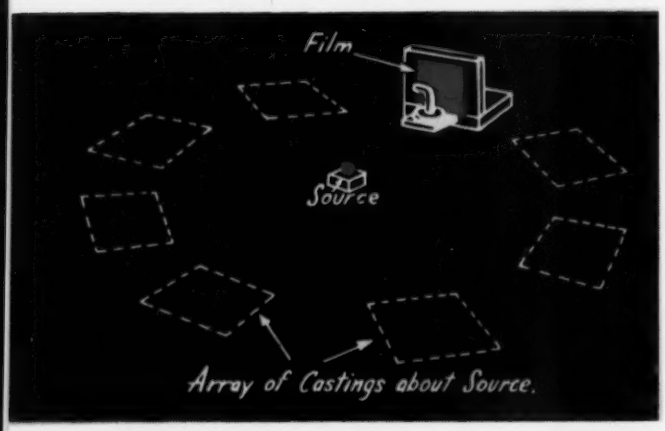



Figure 1 illustrates a typical exposure. The discontinuities which appear on radiographs take on many different forms, depending on their nature. The recorded image on the radiograph is, in effect, a shadow picture of the object that has been placed in the path of the gamma rays. So the relative positions of the object, film and direction of the rays are important factors in obtaining a radiograph of high definition or one that is poor in definition.

Proper interpretation of radiographs requires familiarity with the basic principles of shadow formation. Possibly the most comprehensive method of describing shadow formation is the one given by Emerson[1]. A schematic diagram showing the geometric principles of shadow formation, taken after Doan[2], is reproduced in Fig. 2. Reference to text books[3, 4] will help acquaint untrained technicians to these principles of geometric unsharpness.

## TECHNIQUES

A few of the more popular techniques for radiography with isotopes follow.

**TABLE 2: PENETRAMETER SENSITIVITIES**

| Steel Thickness (in.) | Plat Typo (per cent) | Clarity of Penetrameter | Wedge Penetrameter (per cent) | Clarity of Penetrameter |
|---|---|---|---|---|
| 0.5 - 0.75 | 2.0 | fair | 2.0 | sharp |
| 0.75 - 1.0 | 2.0 | sharp | 2.0 | sharp |
| 1.0 - 3.5 | 1.4 | sharp | 2.0 | sharp |
| 3.5 - 6.0 | 1.4 | sharp | .... | .... |
| 6.0 - 9.5 | 2.0 | fair | .... | .... |

1) The multi-specimen panoramic exposure setup —a group of castings are circled about the source and exposed simultaneously (Fig. 3).
2) The circumferential panoramic exposure setups —the source is centered inside a cylindrical object and a series of films are placed round the object (Fig. 4).
3) The double-wall technique—the source is positioned slightly off from perpendicular and some distance away from the object (Fig. 5). An elliptical view is obtained in this method, frequently used when radiographing welded pipe seams.

## VERSATILITY

Tabulated below are a number of ways in which the radio-cobalt isotopes are employed by Canadian Steel Foundries:

- Radiographing pressure castings with metal thickness range from 1/2 to 9-1/2 in.
- Radiographing pilot castings to improve production techniques and minimize scrap.
- Radiographing risers to see how they are functioning.

- Radiographing "graphite" bottom-pouring ladle stoppers to prevent loss of heats due to faulty stoppers.
- Radiographing unsound areas to assure the complete removal of defects prior to welding.
- Radiographing the welded locations to establish the soundness of the technique.
- Radiographing weld bars or plates to examine the competence of the welders.
- Radiographing groups of castings overnight to save many valuable daytime hours.
- Radiographing castings on location to obviate dismantling the casting from an assembly to transport it to the Radiographic Department. The source is transported in its lead safe to the object to be inspected and radiograph is made on location.

## EXPERIMENTAL WORK—RESULTS

To determine the sensitivities that could be resolved with cobalt 60 on thin sections of steel castings, a National Research Council Wedge Penetrameter[5] was obtained (Fig. 6). This "N.R.C. type calibration wedge" contains three slots with individual depths at any one point on it equal to 5 per cent, 3 per cent and 2 per cent of the thickness of the wedge.

Although the majority of work demands 2 per cent sensitivity, it was decided to further the tests and see whether sensitivities of better than 2 per cent could be obtained. To do this, flat type penetrameters, 1/2-in. wide, 1-1/2 in. long and thickness equal to 2 per cent of the metal thickness being examined, were placed on the top slope of the wedge. Each penetrameter contained drilled holes having diameter of 1T, 2T and 4T where T is the thickness of the penetrameter. The resolved sensitivities would be 1.4 per cent, 2.0 per cent and 2.8 per cent respectively. Table 2 gives the results obtained.

Because many castings demanding radiographic inspection are more than 3.5 in. thick, and since this wedge ranged in thickness from 0 to 3.5 in., the sensitivities obtainable beyond 3.5 in. were also queried by using penetrameters similar to those described. Thus far, Canadian Steel Foundries has encountered castings with metal thickness up to 9.5 in. The results of these inspections are also shown in Table 2.

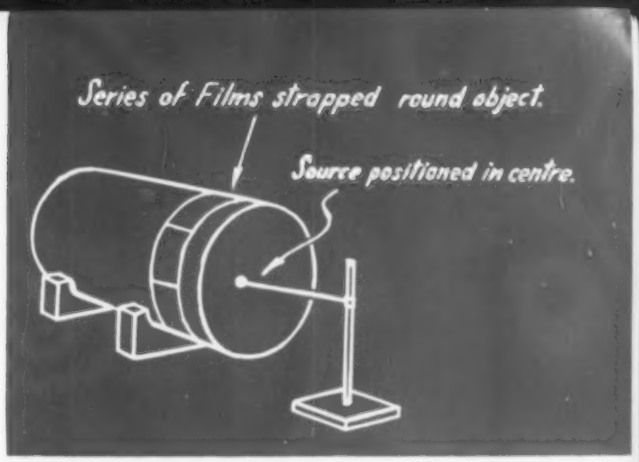



**Fig. 4** . . Gamma ray source is in center of cylindrical object and sheets of film are placed outside.

Most papers and technical books on gamma radiography of steel place a limit of 6.5 in. as the practical thickness range of radiocobalt for a sensitivity of 2 per cent or better. However we have obtained sensitivities of 2 per cent on steel reaching 9.5 in.

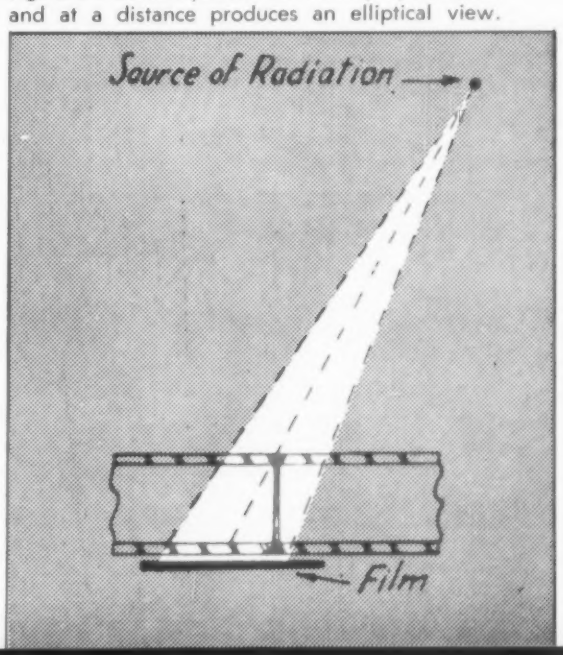
A typical example of this is the recent inspection of segmental and track girders to be used for the

TABLE 1. CHARACTERISTICS OF COBALT-60 ISOTOPES

| Av. Energy (approximate) | Main Line in Spectrum (Mo V) | Radiation Unshielded One Meter Range mR/Hr/mC* | Half-Life (years) | Half Value Layers (approximate) | Source Range (millicuries) | Focal Spot (millimeters) | Average Cost (each) (dollars) |
|---|---|---|---|---|---|---|---|
| 1200 kv | 1.17; 1.33 | 1.35 | 5.3 | ½ in. (lead) | below 100 | 1 | below 200 |
| | | | | 1 in. (steel) | 200 - 500 | 2 | 200 |
| | | equivalent to radiation from 1.55 mg. of radium | | 3 in. (concrete) | 700 - 2000 | 3 | 200 - 300 |
| | | | | | 3000 - 4000 | 4 | 300 - 400 |
| | | | | | 5000 - 10,000 | 5 - 6 | 400 - 600 |

* Milliroentgens per hour per millicurie

**Fig. 5** . . Source placed off from perpendicular and at a distance produces an elliptical view.



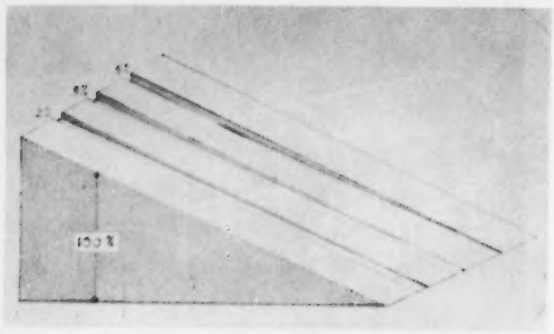


**Fig. 6A** . . Representation of calibration wedge used to determine the sensitivity of cobalt 60.

St. Lawrence Seaway. The metal thickness at the sections requiring radiographic examination were 8.5 in., 9.0 in. and 9.5 in. Though the specifications called for a sensitivity of 4 per cent, sensitivities of 2 per cent were successfully obtained. See Table 2.

The experimental results have led the author to conclude that optimum radiographic sensitivity can be constantly obtained, when radiographing with cobalt 60, if one:

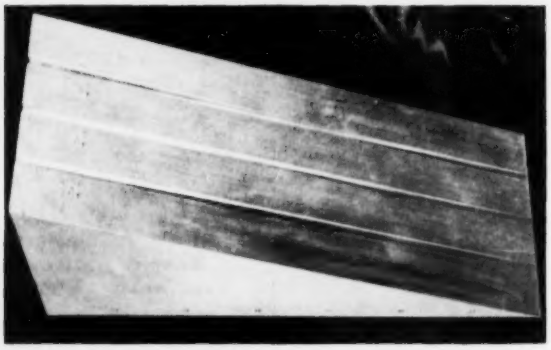
a) Minimizes geometric unsharpness;
b) Establishes a lower limit on the film density when radiographing steel thicknesses below 1.5 in. Densities above 2.5 are best;
c) Uses a fine grain film such as type "M" when radiographing steel thicknesses below 1.5 in.;
d) Uses front lead screens 0.010 in. thick with back screens 0.030 in. thick;
e) Employs a lead "backup" to serve as a shield against back scatter and to act as a weight maintaining the intimate contact between film and screens. The thickness of the lead backup used for these tests was 0.250 in.;
f) Always maintains the temperature of the processing solutions around 68 F.

## ADOPTION OF ISOTOPE RADIOGRAPHY

The following factors serve to illustrate why isotope radiography with radioactive cobalt 60 has been termed a vital tool in our firm:

–It is low in initial investment (See Table 1).
–The isotope has a reasonably long half-life.
–It is readily portable.

**Fig. 6B** . . Maximum section that can be radiographed was determined by using this wedge.



–Radiocobalt is small in size, enabling its insertion into confined locations of complex castings.
–It has a small focal point and a high intensity, permitting short source to film distances.
–The wide latitude of the radiographs allows multi-thick specimens to be exposed on a single film.

■ Besides cobalt 60 there are a number of other radioisotopes available for specific tasks[6]. The metal thicknesses for which these isotopes are best suited are as follows:

| | | |
|---|---|---|
| Cobalt 60 | – approximately | 1.0 in. to 7.0 in. steel |
| Iridium 192 | – " | 0.7 in. to 2.0 in. steel |
| Thulium 170 | – " | 0.2 in. to 1.2 in. steel |
| Sodium 24 | – " | 4.0 in. to 12 in. steel |
| Cesium 137 | – " | 1.5 in. to 4.0 in. steel |
| Tantalum 182 | – " | 1.0 in. to 7.0 in. steel |

This wide selection of isotopes renders possible the inspection of all steel thickness ranging from 0.2 in. to 12 in. The recent construction of nuclear reactors for research on radioactive isotopes augments the author's faith that the field of isotope radiography will continue to expand and that many advances can be foreseen for the future.

## ACKNOWLEDGMENTS

The author wishes to thank the management at Canadian Steel Foundries for their interest and cooperation; and Mr. W. E. Havercroft of the Department of Mines and Technical Surveys, Ottawa, for supplying the calibration wedge photograph and for his interest and helpful comments. Thanks also to Mr. F. Dufour for his cooperation in preparing the tables herein.

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2. G. E. Doan and Shang-Shoa Young, **Gamma-Ray Radiography**, Proceedings, American Society for Testing Materials, v 38, 1938, part II, p 292.
3. H. R. Clauser, **Practical Radiography for Industry**, chapter 6, p 100, Reinhold Publishing Corp., New York, 1952.
4. **Radiography in Modern Industry**, Geometric principles, p 9, Eastman Kodak Co., Rochester 4, N.Y., 1947.
5. Havercroft, W. E., **Training in Industrial Radiography**, *Nondestructive Testing*, v 13 (3), May-June, 1955, p 15.
6. Stewart, P. J., **The Preparation and Handling of Intense Radioactive Sources**, *Nondestructive Testing*, v 13 (3), May-June, 1955, p 11.

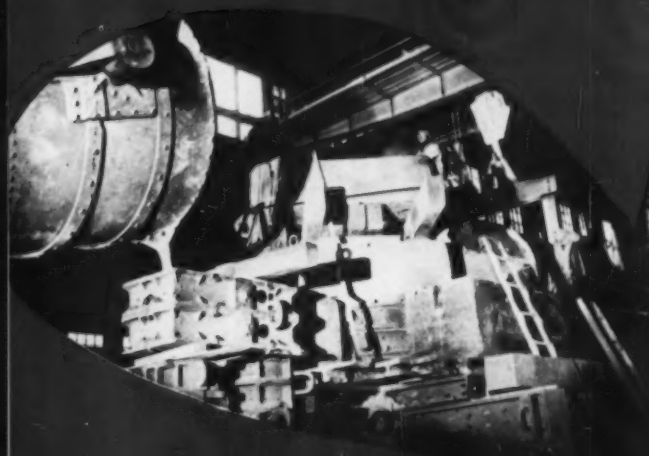
■ To obtain an additional copy of this article, circle No. 239, Reader Service Card, last page.

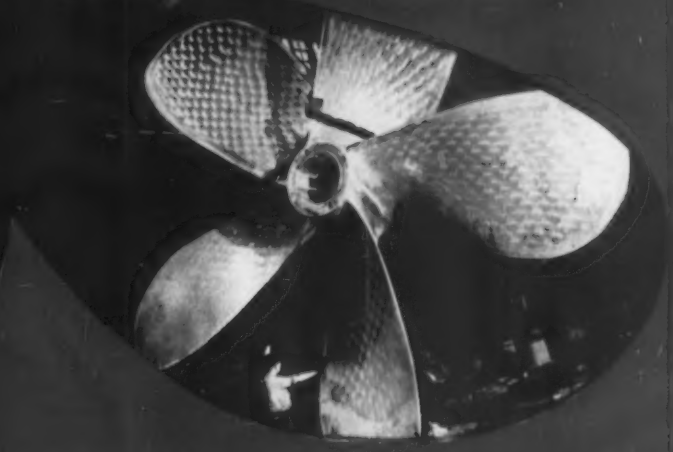
### MORE ABOUT COBALT 60

In this same issue of MODERN CASTINGS, page 73, A. J. Karam, plant manager, Central Foundry Div., GMC, Saginaw, Mich., tells how his company uses cobalt 60 to check new casting designs and to plan gating and risering systems.

For further background in this important subject read "Radioisotopes Utilization in the Foundry Industry," May issue of MODERN CASTINGS. Authors M. Pobereskin and D. N. Sunderman of Battelle Memorial Institute point out that American industry is saving about 500 million dollars a year through the application of radioisotopes!

# BIG WHEEL





## *Supercasting for Supertanker*

This big wheel—24 ft in diameter and weighing close to 37 tons—is one of several record-breaking ship propellers recently cast by the Eddystone Div., Baldwin-Lima-Hamilton Corp., Eddystone, Pa. The giant props are exerting 25,000 hp to push supertankers loaded with 478,000 barrels of oil at a speed of 17 knots.

B-L-H developed a new zinc-free nickel-aluminum bronze alloy to withstand the extreme corrosive cavitation and pitting effects of continual operation in sea water. Alloy permits casting thinner blades which have less drag and thereby increase operating efficiencies. Service tests indicate that the propellers should operate six years without replacement or reworking. Expected savings in 5's years' operation on a Barracuda tanker is predicted to be $170,000.

Foundry operations, such as pattern layout, molding, pattern drawing and mold closing, required five or six weeks' effort prior to pouring. The cement-bonded sand mold received molten bronze simultaneously from two bull ladles. After 10 days slow cooling in the mold, the giant casting could be shaken-out. With aid of pitchometer the exact pitch and contour are hand chipped along ten radii from hub to tip of each blade. Uniform grinding to shape between these radii is followed by machining and boring.

Five-bladed propeller shown at lower right is latest design measuring 24 ft 9 in. across and destined for super-tanker under construction in Japan.

■ To obtain an additional copy of this article, circle No. 240, Reader Service Card, last page.

**Carrier** - - -

# *Uses Castings to Build Air Conditioners*

ROBERT R. STANTON /
*Foundry Technician*
*Carrier Corp.*
*Syracuse, N.Y.*

WENDELL F. IRWIN /
*Foundry Technician*
*Carrier Corp.*
*Syracuse, N.Y.*

Next to the giant automotive industry, more metal castings are probably used in air conditioning, refrigeration and industrial compression than in any other manufacturing group. Carrier Corporation, a leading producer in all three fields, currently purchases approximately 17 million pounds of castings annually, totalling $4,500,000. A wide variety of castings ranging from a simple wedge to an intricate centrifugal compressor come from some 50 foundries across the nation. Carrier's belief in the capabilities of castings makes them one of the biggest users east of the Mississippi.

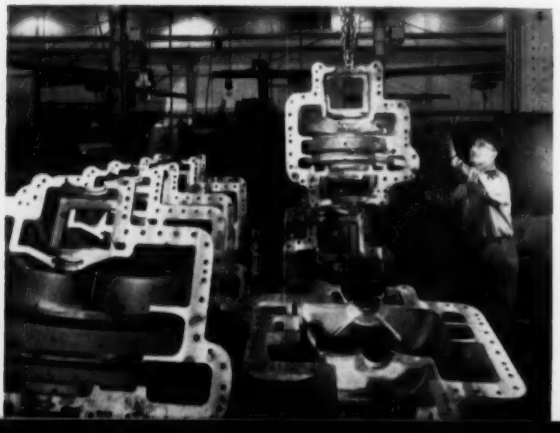
"Weather manufacturing," includes heating and cooling, humidification and dehumidification, filtering, ventilation and circulation of the refined product—air. Portable room units, capable of performing all these functions in a single box and light enough to carry from window to window, use numerous castings in a wide range of alloys both ferrous and nonferrous. The "heart" of this fractional horsepower unit and other air conditioning systems up to about 150 tons cooling capacity is usually a reciprocating compressor. Within its cast shell are 30 to 40 cast parts.

For larger cooling capacities, centrifugal compressors squeeze refrigerant gas through narrow passageways by means of a series of rotors spinning at speeds up to 1500 ft. per sec. This type starts at about 90 tons* capacity and goes to approximately 3500 tons. These complex compressors are about 90 per cent cast parts.

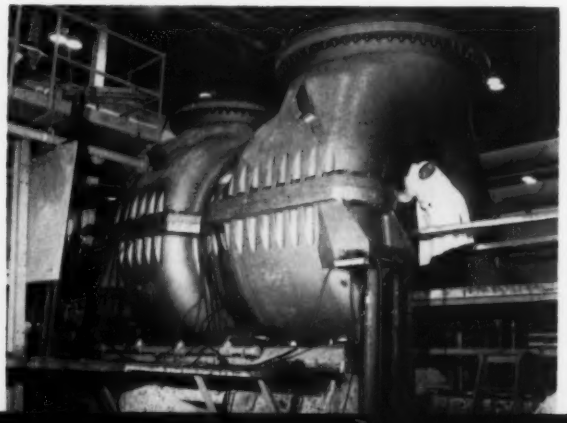
Weights of the vast array of castings required by Carrier cover an impressive span. A dynamic example of those adding up to only a few ounces are two impeller wheels little larger than a silver dollar, used

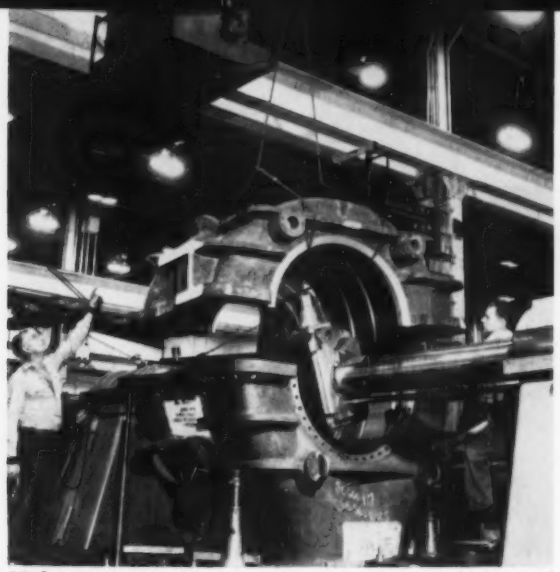
*(One ton of cooling is equivalent to the melting of a ton of ice over a 24-hour period)

**This waiting line** of castings are top halves of compressors for cooling machines. The shells have been faced off and drilled. Next step is to clamp them to lower halves for boring interiors.



**Weighing 45 tons** this cast axial compressor is the largest that could be transported by rail to the Texas butadiene plant where it will be used to pump tremendous quantities of gas.





**80 hours** are required to bore out the two halves of Carrier's largest centrifugal compressor. Shaft of mill is 29 ft long which permits one compressor to be machined while second is being set up on mill.

**In-process inspection** of impellers for high capacity hermetic centrifugal cooling machines assures that they will be finished to specifications. Two of the rotors shown in foreground are used in each machine.

in the compressor-turbine of the air conditioning system for Douglas Aircraft's new DC-8 jet transports. The rotors are on each end of a three-inch-long shaft and spin at supersonic speeds. The rotative assembly inside a compressor, made of cast high-strength aluminum alloys, occupies one-fourth the space of the cooling unit in a household refrigerator and is better than 100 times more powerful.

The "mighty mite" weighs about nine pounds. Together with its two cooling coils approximately the size of airplane luggage, the system provides enough cooling for seven average-size homes.

Typical of the heaviest Carrier castings are top and bottom halves of compressors for Petro-Tex Chemical Corporation. One complete unit weighs in excess of 70,000 lb and occupies the space of a railroad flatcar. Two over-the-road trailer trucks are required to deliver the complex patterns used in its manufacture.

The shape of these compressors was governed by the tremendous volume of gas they would move and maximum dimensions for shipment by rail from central New York to Houston, Texas. In operation, sufficient gas is sucked through their 7-ft diam inlets and discharged out 5-ft diam ports, to supply the round-the-clock needs of a city the size of Chicago.

When centrifugal compressors are applied to petroleum, chemical or petrochemical plants, special process gas streams often require that cast parts be made of high-alloyed metals containing nickel, chromium or molybdenum.

Because of the speeds at which piston or rotating assemblies operate with minimum clearances, precision is of vital importance. For extremely close tolerance jobs, castings are produced by the investment process. However, virtually all other foundry methods —cold set, carbon dioxide, permanent and semi-permanent molding, dry and green sand, die casting, cement ceramics—are used to manufacture the infinite number of castings needed for Carrier air conditioning units.

**Cast iron crankcases** for reciprocating compressors seem to roll along conveyor in endless line. Machine shop in this view is performing final honing operation on cylinder prior to final assembly.

**Precision boring** is required on the inside of cast compressor used to cool stream of gases in production of high octane gasoline. Compressor is expected to operate 8000 hr continuously.

# Report on the ENGINEERED CASTINGS SHOW

## PART II

**This second part of the Engineered Castings Show story concludes MODERN CASTINGS' coverage of the many fine metalcasting exhibits displayed at the AFS 63d Castings Congress in Chicago, April 13-17.**

**Foundrymen demonstrated their ingenuity with a great variety of sizes, configurations, metals and alloys cast to shapes suited to the needs of practically every industry which is using metalcasting.**

**Buyers and designers on hand for the show voiced substantial confidence in the ability of castings to solve many of the fabricating problems facing them today. Each of the following short-stories are numbered for ease of identifying the picture to which the story refers.**

1 Bendix Foundries, Bendix Aviation Corp., Teterboro, N.J., attracted the attention of aircraft, missile and electronic engineers. Bendix specializes in aluminum and magnesium castings made in sand, shell, plaster, permold and dies.

2 One of the salesmen from B-Mold Div., Buckeye Brass & Mfg. Co., Mansfield, Ohio, is explaining the merits of a precision permanent molded aluminum bronze armature finger plate. Besides non-ferrous permanent mold castings, company makes investment and centrifugal castings.

3 The only exhibiting foundry owned and operated by a woman was Castall Precision Products, Chicago. Owner, Miss Alma Zatloukal is pictured showing a casting suited to the needs of two Minneapolis-Honeywell Regulator Co. engineers — R. C. Mott and G. P. Eisenbacher.

PM PRATTON-MITCHEL
LANSDALE, PA.
SILVER

**4** M. J. Siwek, Sales Manager, Chicago Foundry Co., Chicago, talks high strength gray iron to Dale Chapman, Asst. Purchasing Agent, Signode Steel Strapping Co. Signode prefers to use castings whereever possible in building steel strapping machinery.

**5** Investment castings are the subject of this confab between Owen W. Hale, Independent Steel Casting Co., New Buffalo, Mich., and several prospects.

**6** The Nike-Hercules missile contains 74 aluminum and magnesium permold castings. S. J. Joyce, Purchasing Agent, Douglas Aircraft, holds a cast Nike air-duct purchased by Douglas from J. Stevenson of Hampden Brass & Aluminum Co., Springfield, Mass.

**7** Looking over a blue print brought to the Show by C. W. Marshall, Casting Buyer, New Britian Machine Co., Forst L. Robertson (center), Sales Manager, Keokuk Steel Casting Co., Keokuk, Iowa, discusses problems of casting parts for duplicating Swiss lathes with Marshall and H. C. Magnuson, W. Hartford Pattern Works.

**8** Looking over a model of the General Electric Co. new steel foundry, B. A. Kunke, Jr., Purchasing Agent, S & C Electric Co., tells J. P. Finch, Sales Engineer, General Electric Co. about his needs for castings in high voltage switches.

9 Conference in the booth of Paxton-Mitchell Co., Omaha, Neb., centers around a bronze lift nut with threads cast to size so no machining is required—thanks to high-accuracy shell coring.

10 D. L. Redd, Sales Engineer, Rolle Mfg. Co., Lansdale, Pa., is flanked on either side by buying team from Chicago Aerial Industries interested in thin walled castings for aerial photographic equipment.

11 Because his company buys over 100 tons of steel castings a month for axle housings, ripper shanks and cylinder ends, N. G. Olsen, Project Engineer, Tractomotive Corp., had lots of business to talk over with H. P. Tuman, Sales Engineer, Sivyer Steel Castings Co., Chicago.

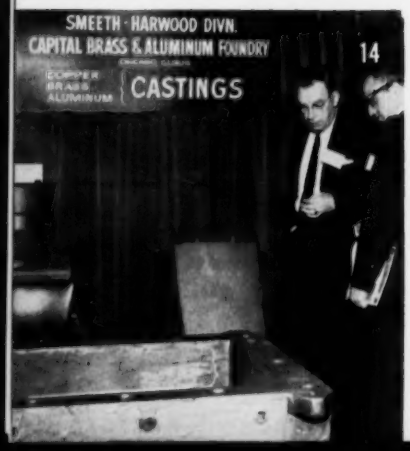
12 D. J. Brozoski, Manufacturing Engineer, Cutler-Hammer, Inc., tells G. A. Zabel, V.-Pres.-Sales, and L. Villivock, Sales Rep., of Universal Foundry Co., Oshkosh, Wis., how his company uses 80,000 lb of nonferrous and 750,000 lb of gray iron castings a year.

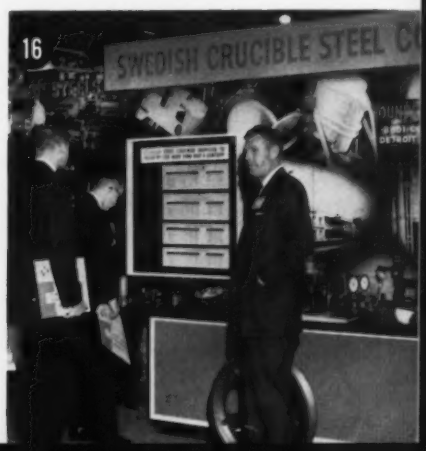
13 Buying a million pounds of ductile iron a month for printing presses is a big job for Purchasing Agent C. K. Schenk and Casting Buyer W. E. Manstrom of The Miehle Co. In center is W. J. Meinhard, Asst. to Pres., Lindgren Foundry Co., Batavia, Ill., showing them a crankshaft driving gear for a vertical press.

14 Large water-cooled copper door frame for reverberatory furnace is subject of conversation between H. N. White, Smeeth-Harwood Div., Capital Brass & Aluminum Foundry, Chicago, and a visitor.

15 Discussing the possibility of permanent mold casting of over one million theatre seat frameworks are J. V. Meulen, American Seating Co. and G. W. Stahl, owner, Stahl Specialty Co., Kingsville, Mo. Their specialty is permanent mold casting of aluminum.

16 A part of the Swedish Crucible Steel Co. exhibit at the Engineered Castings Show featured plastic coated steel castings for corrosion resistance and electrical resistance.





# Report on the TECHNICAL PROGRAM

## PART II

More than 95 technical papers were presented at the 63d AFS Castings Congress in Chicago during April. Most of these have been, or will be, published in full in MODERN CASTINGS. However, MODERN CASTINGS has also published an abstract of every paper, panel or seminar presented to the Castings Congress. This article completes the presentation of abstracts.

One unusual highlight of the technical activities of the 63d Castings Congress that is pictured on these pages is the presentation of the first Gray Iron Division Award for the outstanding paper presented to that division of AFS. The 1959 award was won by the paper, "Martensitic White Irons for Abrasion Resistant Castings," which was authored by T. E. Norman, A. Solomon and D. V. Doane. The committee which selected this paper for the award considered that it was, "unusually well organized with the information presented in such a manner as to be readily understandable to the reader."

### C. E. HOYT LECTURE

**The Control of Quality in the Brass Foundry by *Harry M. St. John.*** St. John presented the philosophy of foundry control and described the two basic aims of control programs as control to guard against the delivery of unsatisfactory castings to the customer, and to control loss of profit due to the production of defective castings. St. John stated that a complete control program will cost both time and money, but will yield returns out of all proportion to the cost.

### DUCTILE IRON PAPERS

**Ductile Iron As-Cast and Annealed Tensile Properties by *A. H. Rauch, J. B. Peck and E. M. McCullough.*** The authors' study revealed the existence of a relationship between tensile properties and Brinell hardness in as-cast pearlitic-ferritic ductile iron. However, they discovered, these relationships are strongly affected by changes in the composition of the iron . . . . . **Heat Treatment of Ductile Iron by *W. D. McMillan.*** The author considered the heat treatment of ductile castings on a tonnage basis. His discussion covered three types of treatment set up to process the castings . . . . . **Carbon Flotation in Ductile Iron by *A. H. Rauch, J. B. Peck and G. F. Thomas.*** Studies by the authors disclosed that in hypereutectic ductile iron castings, carbon in excess of that necessary to maintain a carbon equivalent of 4.55 per cent is precipitated during solidification . . . . . **Ductile Iron Production in Basic Direct-Arc Furnace by *C. R. Isleib.*** The author described how a basic-lined, direct-arc furnace can save addition alloy costs, reduce reladling, and reduce the tendency toward drossing . . . . . **Tin Effect on Structure and Properties of Flake and Nodular Grahpite Cast Irons by *E. C. Ellwood.*** The author described new studies on the effect of tin on the promotion of pearlitic matrices in two nodular irons. The tin effect on the mechanical properties of such irons was also presented . . . . . **Ductile Iron Castings versus Carbon Steel Forgings and Weldments by *J. L. Salbaing.*** The author described the ad-

Ductile and Gray Iron luncheon audience was informed about the requirements of casting designers by T. O. Kulvinen.

Heat Treatment session featured D. J. Albanese, A. Bain, J. L. Filtz, E. S. Frost, J. F. Wallace, J. O. Henzel, R. W. Ruddle.

vantages of ductile iron castings over carbon steel forgings and weldments in terms of metal structure, isotropy and directionality, strength and production.

## FUNDAMENTAL PAPERS

***Mass Effect on Castings Tensile Properties by G. W. Form, P. J. Ahearn and J. F. Wallace.*** The authors' study produced the hypothesis that tensile strength is reduced by increasing solidification time if the ductility during tensile testing is insufficient to exceed the necking strain. However, as long as the metal is sufficiently ductile to exceed this limiting value, the tensile strength is virtually unaffected by changing solidification times . . . . . ***Dimensioning of Sand Casting Risers by H. D. Merchant.*** The author presented a new approach for risering sand castings whereby a general equation for risers is developed. Using the equation, the size of riser or risers for a given casting can be easily found . . . . . ***Linear Programming Applied to Economic Selection of Materials for Furnace Charges by Gideon I. Gartner.*** The author described a technique by which the infinite combinations of charge materials may be compared to determine which combination is the most economical . . . . . ***Solidification of Gray Iron by Albert De Sy.*** The author presented a study into the fundamental mechanisms involved in the transformation of iron from the liquid to the solid state. He noted that once the mechanisms of change are known, the desired change can be obtained with minimum time and effort . . . . . ***A Fluidity Test for Aluminum Alloys; Tripling Fluidity with a New Mold Coating by M. C. Flemings, H. E. Conrad and H. F. Taylor.*** The authors described a fluidity test using a sand mold with a metal screen in the runner. Also described was the use of hexachlorethane as a mold coating. This material was found to improve fluidity 200 percent . . . . . ***Mechanical Properties and Processing Techniques for High Strength Steel Castings by K. D. Holmes, J. Zotos and P. J. Ahearn.*** The authors described a series of tests of test coupons and castings which disclosed that the best combination of strength, ductility and toughness was obtained in thin sections of low sulphur and phosphorous steel cast from arc furnace heats . . . . . ***Structural Variables Influencing Mechanical Properties of High Strength Cast Steels; A Progress Report by M. C. Flemings, Robert Green and H. F. Taylor.*** During their study, the authors noted that differences in solidification conditions did not affect the macrostructure appreciably, but changed the microstructure in important ways . . . . . ***Grain Refinement of Solidifying Metals by Vibration by R. G. Garlick and J. F. Wallace.*** Studies conducted by the authors substantiated the theory that vibration, with its alternate high and low pressure waves, increases the nucleation rate of the solidifying phases . . . . . ***Application of Theory in Understanding Fluidity of Metals by J. E. Niesse, M. C. Flemings and H. F. Taylor.*** The authors presented a theoretical analysis of the fluidity of pure metals employing heat flow and fluid flow relationships. Equations were developed to predict fluidity of pure metals at their melting point and to predict the effect of superheat on fluidity

Sand Shop Course reviewed techniques for air-set and $CO_2$ binders.

K. D. Prosser at Gray Iron Shop Course on melting irons in one heat.

Belgium's Albert DeSy describes mechanisms of melting in a Fundamental Paper.

Gray Iron Session personalities were: R. Shnay, J. Wilson, W. Moore, D. Krause, M. Horton, H. Henderson, K. Presser.

Past Presidents at head table were: Collins, Dietl, Wagner, Bishop, Bornstein, Shipley, Wells, Wallis, Seabeck and Obrecht.

. . . . . **Development of low Alloy Steel Compositions Suitable for High Strength Steel Castings by H. R. Larson and F. B.** . . . . . **Development of Low Alloy Steel Herlihy.** The authors described an investigation whose ultimate goal is to produce high integrity castings for airframe structural components . . . . . **Comparison of X-Ray Quality and Tensile Properties in Cast High Strength Steel by H. R. Larson, H. W. Lloyd and F. B. Herlihy.** The authors described a study of properties in simple shapes in which unsoundness is present in varying degrees.

## GRAY IRON PAPERS

**Molybdenum Effect on Gray Iron Elevated Temperature Properties by G. K. Turnbull and J. F. Wallace.** The authors presented a study of the effect of up to 2.0 per cent molybdenum on the short-time tensile and stress-rupture properties of a 3.8 per cent carbon equivalent gray iron by various additions of that alloy to two base irons . . . . . **Mold Material Effect on Cooling Rate and Physical Properties of Cast Metals by Sub-Committee T.S.46, Technical Council, Institute of British Foundrymen.** The committee's report detailed a study of the effect on the physical properties of various cast irons when cast into molds made in typical molding sands at various ramming densities, and also the effect when using other types of molding materials of varying thermal properties . . . . . **Factors Influencing Soundness of Gray Iron Castings by I. C. H. Hughes, K. E. L. Nicholas, A. G. Fuller and T. J. Szajda.** These British authors reported on a study which disclosed that increasing the degree of nucleation of the graphite eutectic leads to unsoundness. They noted that this is a common foundry variable which can be measured, and is amenable to some control . . . . . **Ductility and Strength of High-Carbon Gray Irons by E. M. Stein and H. O. McIntire.** The authors evaluated the composition, microstructure and inoculation effects on ductility and strength of high-carbon cast irons. Irons melted by cupola, induction and blast furnace were included in the study . . . . . **Gray Cast Iron Machinability by W. W. Moore and J. O. Lord.** The authors studied common types of unalloyed cupola-melted gray iron to determine how changes in some of the major constituents of their microstructures affected machinability . . . . . **Martinsitic White Irons for Abrasion-Resistant Castings by T. E. Norman, A. Solomon and D. V. Doane.** The authors described studies into the important variables influencing structure, wear resistance, mechanical properties and resultant service life of martensitic white iron castings . . . . . **Radioisotopes Utilization in the Foundry Industry by M. Poberskin and D. N. Sunderman.** The authors reported that the widespread uses of radioisotopes in the metals industry do not require new techniques, but only the application of already developed techniques to new problems . . . . . **Copper in Cast Iron by Albert de Sy.** The author reported that copper additions improve machinability and wear resistance and are relatively inexpensive . . . . . **Continuous Carbon Injection by J. E. Wilson and R. C. Shnay.** The authors decribed a development program which led to satisfactory equipment, procedures and controls for continuous carbon injection on a commercial, production basis. . . . . **Significance of Reported Chemical Analysis of Cast Iron by D. E. Krause.** The author discussed the importance of recognizing the fact that different laboratories will report varying analyses of identical iron samples. He noted that these differences are important when evaluating the relation of chemical composition of cast iron to its mechanical and physical properties . . . . . **Foundries Can Produce Their Own Cast Iron Directly from Ore by H. W. Lownie, Jr. and A. J. Stone.** The authors reported that foundries might increase their profits by using some recently developed direct-reduction processes for producing iron. Some of these processes are suitable for integration into a foundry to replace cupolas . . . . . **Gray Iron Shop Course: How to Melt Several Irons in One Heat.** Panel member K. G. Presser emphasized that when melting several irons, the foundryman must make the best advantage of every control tool at his command. Panel member M. D. Neptune described various foundry controls found to help in the production of several irons in a single heat . . . . . **Gray Iron Shop Course: Correction of Cupola Irregularities by W. W. Levi, M. H. Horton and D. E. Krause.** Three of the top cupola experts in the country explained the irregularities in operation that led to the iron being either too hot, too cold, too hard or too soft. The three-man panel then answered a variety of questions posed by the large gathering of foundrymen present. . . . . **Ductile and Gray Iron Round Table Luncheon: What Does the Casting Designer and Buyer Expect of the Foundryman by T. O. Kuivinen.** The speaker exhorted foundrymen to reduce the factor of ignorance on the capabilities of castings and thereby reduce the unreasonable factor of safety loaded onto castings. Added highlight of the luncheon was presentation of the Gray Iron Division Award to T. E. Norman, D. V. Doane and A. Solomon for their paper Martensitic White Irons for Abrasion Resistant Castings.

## HEAT TRANSFER PAPERS

**Modern Quenching Oils and Techniques for Foundry Heat Treating by N. F. Squire.** The author discussed the increasing importance of the quenching phase of heat-treating steels and the variables that effect the results. Case histories showing results of using an additive-type quenching oil medium were presented . . . . . **Solidification Times of Simple-Shaped Castings in Sand Molds by J. T. Berry, V. Kondic and G. Martin.** The authors described experiments made to check the assumptions made in applying the basic mathematical treatment of the rate of solidification to sand cast shapes.

## SAND PAPERS

**Sand Movement and Compaction in**

**Green Sand Molding by T. J. Bosworth, R. W. Heine, J. J. Parker, E. H. King and J. S. Schumacher.** The authors presented a description of the principles controlling sand movement during squeezing, jolting and contour squeezing. The compaction process, and development of mechanical properties with increasing density, was also described . . . . . **Tempering Molding Sand by H. W. Dietert, V. Rowell and A. L. Graham.** Test procedures for actual and compensated moisture tests were described by the authors. The actual moisture test was recommended whenever the actual total percentage of base water and water of evaporation is required. The compensated moisture test was recommended for determining the sand moisture content without including the evaporation water . . . . . **Experimental Determination of Specific Surface and Grain Shape of Foundry Sands by Franz Hofmann.** The author described a method, referred to as the permeability method, of determining the actual specific surface of sand . . . . . **Green Tensile and Shear Strengths of Molding Sands by R. W. Heine, E. H. King and J. S. Schumacher.** The authors detailed the principles relating to tensile and shear properties, their relation to other green sand properties and their connection with molding problems . . . . . **Timing of Expansion Scab Formation by J. E. Haller.** The author described a study of mold surface penetration designed to find when expansion scabs occurred. The tests showed that one type of scabs and/or buckles occurred because of sand expansions, and occurred while the metal was still in a liquid stage . . . . . **Introduction of a Tentative Hot Shell Deformation Test by R. J. Cowles.** This paper, a report of the Shell Mold and Core Committee (8-N), presented the principles of a tentative hot shell deformation test as well as representative data which would be expected for acceptable operations . . . . . **New Foundry Resins and Application Techniques for Shell Molds and Shell Cores by William C. Capehart.** The author presented a discussion of the operational problems, corrective measures and control measures encountered in the use of shell molds and cores . . . . . **How to Avoid Sand Segregations a joint report of Committee 8-F, AFS Sand Division and the Grading and Fineness Committee, National Industrial Sand Association.** This report presented recommendations for controlling segregation during loading and unloading operations . . . . . **Crust Separation Test for Investigating Sand Expansion Defects by P. W. Goad.** The author described development of a new technique for studying expansion defects. This officially sponsored exchange paper from the Institute of British Foundrymen, Australian Branch (Victoria) points to moisture content of sand as a vital factor in determining the nature of expansion defects and susceptibility of the sand mix to this defect . . . . . **Stickiness in Core Sand Mixtures.** The final progress report of AFS Sand Division Committee 8-K noted that no test suitable to become a standard has been developed, but that procedures satisfactory for correlating production results have been evolved. . . . . **Effects of Ramming, Superheat and Alloy Penetration by George Vingas.** The report of AFS Sand Division Committee 8-H as presented by the author consisted of a statistically controlled, quantitative evaluation of the effects of absolute temperature, relative temperature and void size . . . . . **Critical Sodium Silicate-Sand Formulations for Optimum $CO_2$ Molding by R. J. Cowles.** The author reported the problem of poor collapsibility in $CO_2$-bonded sands can be overcome by controlling the amount of sodium silicate used in the sand mix. A simple laboratory test Panel member F. P. Ilenda described methods of curing molds with $CO_2$ and types of castings suitable for application to the process. C. W. Sundberg, second $CO_2$ can be used to establish the optimum amount of sodium silicate . . . . . **Sand Shop Course: Air-set and $CO_2$ Binders.**

*Continued on page 136*

# 1959 CASTINGS CONGRESS PAPERS

■ The technical articles appearing in this preview section of MODERN CASTINGS are the official 1959 AFS Castings Congress papers—the most authoritative technical information available to the metalcasting industry.

Nearly 100 technical papers presented at the 63d Castings Congress of the American Foundrymen's Society will be printed here prior to publication of the complete 1959 AFS TRANSACTIONS.

■ Written discussion of these papers is welcomed and will be included in the 1959 TRANSACTIONS if submitted by September 1. Discussions should be addressed to the Technical Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

■ The complete case-bound volume of 1959 AFS TRANSACTIONS, including all papers and all discussion, will be published December 1. Orders for this volume should be addressed to the Technical Department.

# COPPER IN CAST IRON

## *principal considerations*

By Albert de Sy


### ABSTRACT

**Copper is a graphitizer at the stage of solidification as well as an anti-ferritizer through transformation range cooling. Because of this, copper additions to gray cast iron prevent thin section chilling and formation of free ferrite in heavy sections. A uniform structure is thus imparted to gray iron by the copper additions which has neither hard nor soft spots, and has good overall strength and hardness properties.**

**Thus, copper additions offer a distinct advantage in relation to machinability and wear resistance which are important for the many applications and engineering properties of gray iron castings. Also, compared to other alloying elements, copper is relatively inexpensive.**


## I. THEORETICAL CONSIDERATIONS

It may be said that the art of using basic or general scientific knowledge is to analyze complicated matter systematically, and to look at it carefully in the simplest possible way. This should undoubtedly apply to gray cast iron, which is a complicated alloy, mainly because of the superposition of two crystallization systems and owing to the allotropic transformation of iron.

Moreover, any element added to the basic ternary alloy Fe-C-Si affects the relative importance of the two crystallization systems and influences the transformations on cooling. Therefore, any element, even when present only as a trace, affects the final structure and, consequently, the physical properties of the alloy. The physical properties are determined by the structure, and thus it is important to analyze the structure and structure modifications resulting from the addition of an alloying element such as copper, which is to be considered here in particular.

In studying the structure of a multiphase alloy it is desirable to proceed in two parallel but slightly different ways, viz., by considering the different constituents on the one hand and the different phases on the other hand. Apart from inclusions, and even apart from iron phosphide and free cementite which will not be considered here, gray cast iron is an aggregate of the constituents pearlite, free ferrite and graphite; or of the phases ferrite, cementite and graphite.

The physical properties of any multiphase alloy, and of gray cast iron in particular, depend on the physical properties of the different phases present, their amount, the form and size of the particles of each phase and on the distribution of the different particles and their association in the so-called constituents.

Thus, it is evident that the study of the effect of copper, or of any other element on the properties of gray cast iron, requires a careful examination of the effect of that element on the above mentioned factors of influence. In reviewing the various copper effects on gray cast iron, it is desirable to distinguish between its direct effect (effect on the properties of the individual phases) and its indirect effects (those concerning the other factors of influence).

### Copper Direct Effect

Copper has practically no direct effect on the properties of the graphite phase in which it is insoluble, and may only be present in graphite as a few entrapped atoms. Moreover, the physical properties of graphite compared with those of the metallic matrix are negligible. This also applies to its effect on the physical properties of cementite. Copper is not a carbide-forming element, and its partition coefficient is such that only a few copper atoms can be dissolved in cementite whose physical properties thus remain practically unaffected.

The physical properties of the ferrite phase, by far the largest in amount, on the contrary are affected greatly by copper additions. Ferrite is hardened by the normal solution hardening in any case, and eventually, in a second step by structural hardening.

Figure 1 gives indications of the solution hardening effect of copper, according to A. Kussman and B. Scharnow,[1] compared with that of several other common elements, according to E. C. Bain.[2] Thus, it appears that copper has a strong hardening effect. Figure 1 as such does not apply for the ferrite phase of cast iron, because the effect of the various elements is not simply additive. Moreover, although elements such as Cu, Si and Ni are entirely dissolved in ferrite this is not so for the carbide forming elements Mn, Mo, V and Cr, which dissolve partly in ferrite and partly in cementite.

The direct effect of copper on gray cast iron thus is limited to its hardening effect on the ferrite phase. On this basis alone, it can be expected that copper additions to gray cast iron will increase both hardness and strength characteristics.

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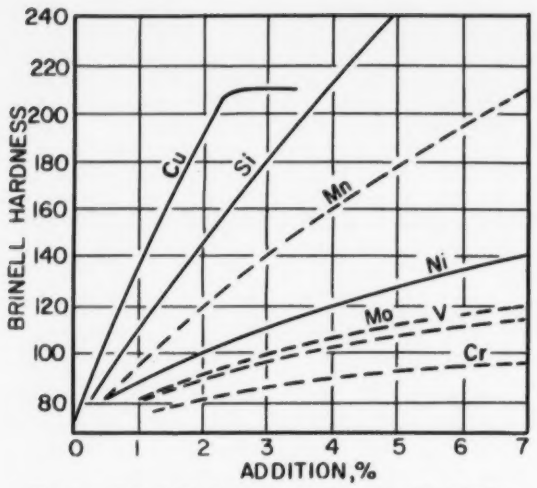



Fig. 1 — Brinell hardness of α — Fe and solid solution hardening effect of various elements.

## Copper Indirect Effects

When considering the indirect effects of copper we have to deal with all other factors of influence, viz., the influence of copper on the amount of the different phases, its influence on the form, size and distribution of the different phase particles and its influence on the association of phase particles in constituents. All these influence factors have to be studied in close correlation to the formation and transformation of the different phases. Consequently, it is necessary to review these copper effects in intimate correlation to the mechanism of solidification and of transformation in the solid state.

*At the Solidification Stage: Copper Is a Mild Graphitizer.* This effect is well known. According to technical literature, the graphitizing effect of copper is estimated between ⅓ and ⅕ that of silicon. According to the author's experience, it should be rather close to ⅕ that of silicon. Consequently, copper is a milder graphitizer than nickel whose graphitizing ratio is ⅓-¼ that of silicon.

The graphitizing effect of Si, Ni, Cu . . . is believed to be in relation to atom prearrangements in the melt just above and at the solidification temperature. As these elements have no tendency to form carbides, they increase the carbon activity of the melt through a dilution effect. Moreover, Si because of its affinity for Fe has a tendency to form Fe-Si prearrangements in the melt. Thus, C atoms tied up by Fe atoms are liberated and the carbon activity of the melt is once more increased.

However, apart from its graphitizing effect, copper also has a structural refining effect. Figures 2 and 3 show the influence of copper on the structure of the chilled zone in rollers and wheels according to P. Van Bleyenberghe and R. Coussement.[3] This effect is of course beneficial, since hardness is lightly increased and brittleness is considerably decreased.

## Copper Refining Effect

The copper refining effect on graphite is less apparent because of the difficulty in estimating it in the case of flake graphite. However, it is distinctly apparent in the case of spheroidal graphite. The refining effect of copper on cementite (and ledeburite) and graphite is an indirect result of an adverse influence of copper on the carbon diffusion rate, and consequently a decreased growth rate of carbon (graphite) or carbon-rich (cementite) crystals. Smaller individual crystals necessarily mean a larger number.

It is not known, at least to the author's knowledge, whether copper has a direct influence on graphite nucleation or (very unlikely) on cementite nucleation. *Transformation in the Solid State: Copper is a Powerful Anti-ferritizer, and Consequently an Equally Powerful Anti-graphitizer.* On the cooling of gray cast iron from solidification to room temperature free ferrite formation may occur in two different ways:

1) Direct ferritizaton according to the reaction
austenite ⇒ ferrite + graphite
or precipitation of ferrite from austenite and also precipitation of the corresponding stoichiometric carbon which crystallizes on the already existing graphite crystals.
2) Indirect ferritization according to the reaction
austenite ⇒ pearlite ⇒ ferrite + graphite
or ferritization and graphitization as a result of pearlite decomposition.

The influence of copper on the first stage reaction

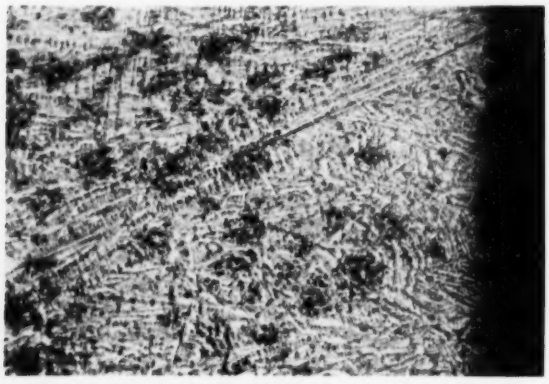


Fig. 2 — Cu = 0%; Rc = 55-57.

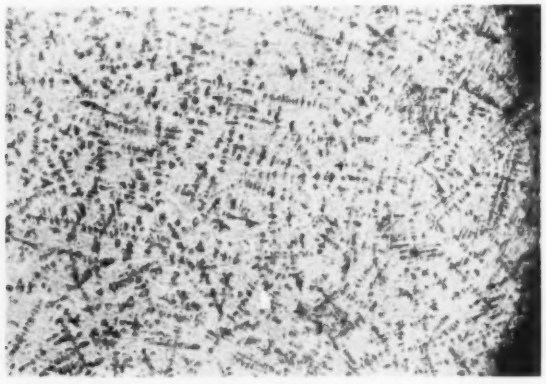


Fig. 3 — Cu = 1.5%; Rc = 60-65.

Figs. 2 and 3 — Copper effect on structure of chilled cast iron. 50 ×.

(direct ferritization) has been carefully studied by A. de Sy, J. Vidts and J. Van Eeghem,[4] and by A. de Sy and J. Foulon.[5]

Figures 4 through 7 show some suggestive results of these investigations. They present a good idea of the anti-ferritizing power of copper as compared with nickel and with tin. Figure 4 shows the structure of a spheroidal graphite iron as-cast in ¾-in. diameter section. It is a high carbon, low manganese and, for that type, a rather low silicon iron. However, the matrix is at least 70 per cent ferritic.

The large ferritic bulls-eyes undoubtedly result from the direct ferrization-graphitization reaction. In order to comparatively study the anti-ferritizing power of Ni, Cu and Sn, various amounts of these elements were added to identical melts prior to the magnesium treatment which was done with a magnesium-ferro-silicon alloy.

Nickel additions of 1.6 per cent, 3.2 per cent, 4.8 per cent and 6.4 per cent were successively made, and none of these additions succeeded in eliminating the ferrite bulls-eyes. Figure 5 shows the result obtained with a 1.6 per cent Ni addition. The result obtained with the 4.8 per cent Ni addition was equivalent to the 0.2 per cent Cu addition. The 6.4 per cent Ni addition resulted in a more or less acicular matrix structure, but still did not completely eliminate the ferritic bulls-eyes.

Thus, it appears that nickel acts as a mild anti-ferritizer. Copper, on the contrary, is a more powerful anti-ferritizer. Copper additions of 0.2 per cent, 0.8 per cent, 1.6 per cent and 3.2 per cent were made and, as shown Fig. 6, the 0.8 per cent copper addition was sufficient to eliminate the bulls-eyes and give a fully pearlitic matrix. Thus, it appears that copper is a powerful anti-ferritizer.

As is well known, high copper contents have an adverse influence on spheroidal graphite formation. It is worth while stating that the 3.2 per cent copper addition completely destroyed the graphite spherulites.

In the same series of experiments the fully pearlitic matrix was obtained with a 0.06 per cent Sn addition, resulting in a 0.03 per cent residual tin content. This powerful anti-ferritizing tin effect has been recently confirmed by J. A. Davis, D. E. Krause and H. W. Lownie.[6]

Of course, the anti-ferritizing effect of copper, tin and other elements is not limited to spheroidal graphite iron. A. de Sy and J. Foulon[5] have shown that it also applies to flake graphite iron, as confirmed recently by J. A. Davis, D. E. Krause and H. W. Lownie.[6] There is only a quantitative difference. Flake graphite irons necessitate larger amounts of anti-ferritizing additions because of the much larger graphite-austenite interface surface.

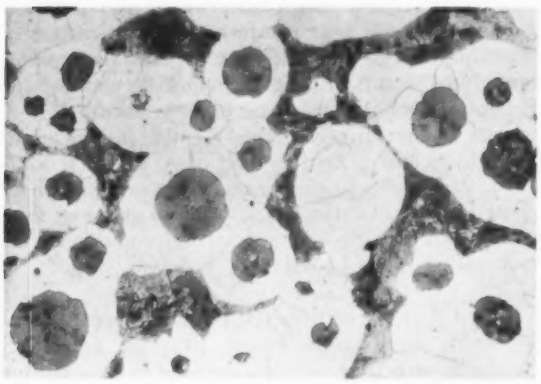


Fig. 4 — C — 3.93%; Mn — 0.27%; Si — 2.02%; Mg — 0.051%.

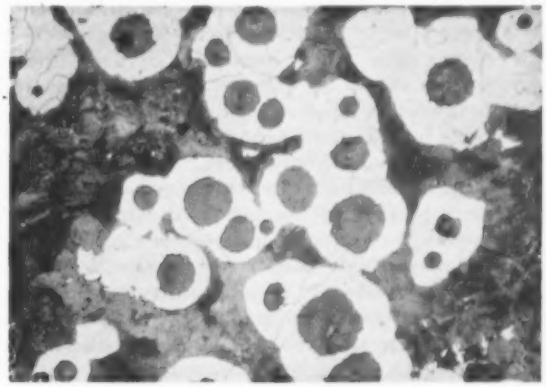


Fig. 5 — Same as Fig. 4, with addition of 1.6% Ni.

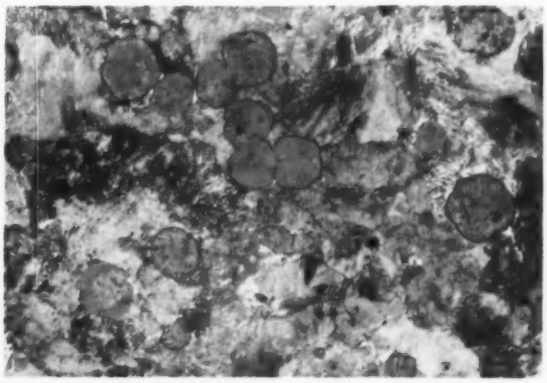


Fig. 6 — Same as Fig. 4, with addition of 0.8% Cu.

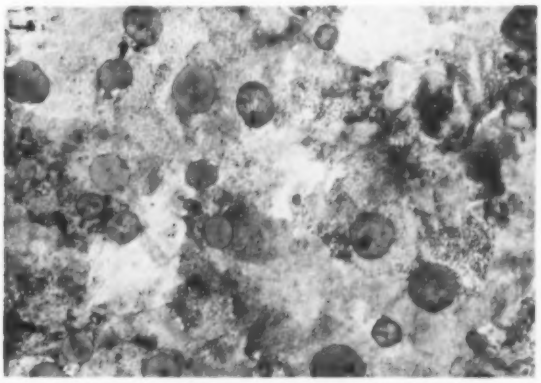
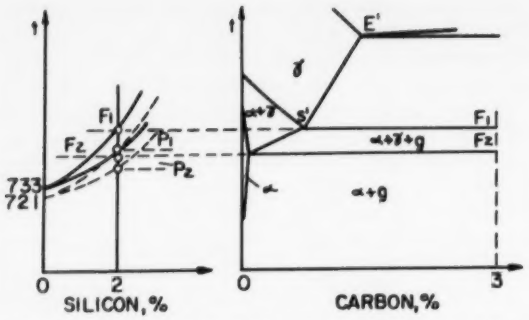


Fig. 7 — Same as Fig. 4, with addition of 0.03% Sn.

Figs. 4, 5, 6, and 7 — Anti-ferritizing power of copper as compared with nickel and tin in a spheroidal graphite iron. 200 ×.




Figs. 8a (left) and 8b (right) — Fe-C-Si system, 2% Si (8a) and 3% C (8b) sections, according to Hanemann and Schrader.[7]

The author does not claim to have discovered the anti-ferritizing effect of copper, only, perhaps, the term. This effect of copper has long been known, but it is stated in the wrong way and generally misunderstood. Indeed, in many technical papers it is said that copper is a pearlite stabilizer, and that is fundamentally wrong. However, it is correct to say that copper is a pearlite formation promotor, as may be easily understood from the study of the mechanism of austenite transformation on cooling.

Figures 8a and 8b represent, respectively, the 3 per cent C and the 2 per cent Si sections of the Fe-C-Si system, according to H. Hanemann and A. Schrader.[7] From Fig. 8a it appears that the direct transformation of austenite to ferrite and graphite may proceed in the temperature range comprised between the F curves (from $F_1$ to $F_2$ at 2 per cent Si). If an iron sample is held in this temperature range, transformation will proceed until equilibrium, provided the holding time is sufficiently long.

The mechanism of this direct transformation is illustrated by Figs. 9a, 9b and 9c, in which graphite is supposed of the spheroidal type for schematic representation facilities only. The reaction invariably starts at the existing graphite-austenite interfaces (Fig. 9a). This results in graphite deposition on the already existing graphite crystals, and in the formation of ferrite layers tending to separate the graphite crystals from the austenite.

Figure 9b represents a stage where the graphite crystal is already completely surrounded by a ferrite layer. From this stage on any further progress of the reaction not only implies ferrite precipitation at the austenite-ferrite interface, but also carbon diffusion from austenite through the ferrite layer to the graphite crystal.

The transformation of, say 100 g austenite containing 1 per cent carbon, results in the formation of approximately 99 g of ferrite and 1 g of graphite. Direct ferritization and corresponding graphitization are stoichiometrically bound. The former is impossible without the latter. The mechanism of this reaction being now clearly understood, it is worth while examining how the presence of copper is able to retard this reaction.

As is well known, copper is an austenite stabilizer. Therefore, as the ferritizing reaction proceeds further, copper must concentrate in austenite as, for an analogous reason, silicon concentrates in ferrite. Thus, increasing copper concentration in austenite corresponds to increased austenite stability, and consequently to a lower reaction rate.

However, the retarding effect based only on austenite stabilization is probably unimportant, since nickel has an equal or even higher austenite stabilizing effect but does not substantially retard direct ferritization.

### Diffusion Barrier

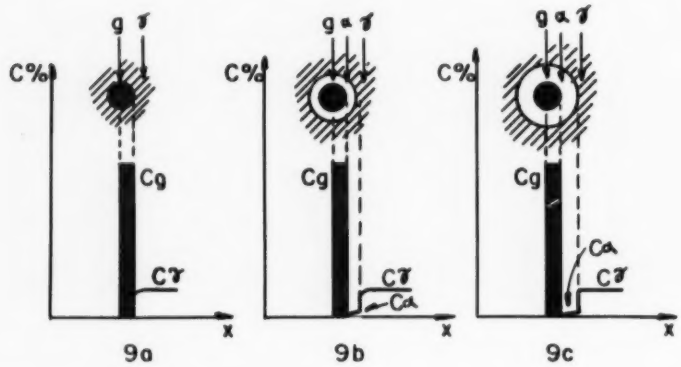
Therefore, it is believed that copper, contrary to nickel, diffuses slowly in austenite, thus accumulating in austenite at the austenite-ferrite interface, to create a diffusion barrier. This theory which may probably be checked in the near future by x-ray diffraction or x-ray fluorescence gives, at least, a plausible explanation of the anti-ferritizing influence of copper, and perhaps also of tin and some other elements.

If, as is conclusively proved by the investigations of A. de Sy and J. Foulon[5] and of A. de Sy, J. Vidts and J. Van Eeghem,[4] copper retards or prevents direct ferrite formation during the cooling of gray cast iron, it thus indirectly promotes pearlite formation in the temperature range between the P curves (from $P_1$ to $P_2$, Fig. 8a).

Indeed if austenite does not transform according to the stable equilibrium system, it must necessarily transform according to the metastable equilibrium system in a slightly lower temperature range.

Thus, copper is a strong pearlite promoter, which is quite different from saying that copper is a pearlite stabilizer.

In concluding the study of the copper-graphite




Figs. 9a (left), 9b (center) and 9c (right) — Schematic illustration of the mechanism of direct transformation of austenite to ferrite and graphite.

correlation in gray cast iron it may undoubtedly be stated that:

1) Copper is a mild graphitizer at the solidification stage.
2) Copper is a powerful anti-graphitizer (which means the same as anti-ferritizer) on cooling through the allotropic transformation range.
3) Copper slightly refines the graphite.

To review completely the copper effect on structure, and consequently on the properties of gray cast iron, it is also necessary to examine its influence on the structure of the constituent pearlite.

As already stated, copper is an austenite stabilizer, from which it automatically follows that the pearlite formation temperature is lowered and the pearlite structure must be finer. That already formed pearlite is stabilized by the presence of copper appears unlikely, but accurate data on this point are not yet available. In reviewing, on the basis of the theoretical considerations given above, the overall effect of copper on gray cast iron, it may be stated that:

1) Copper, being a mild graphitizer, at the solidification stage, tends to decompose or to prevent the formation of ledeburitic carbides.
2) Copper, because of its anti-ferritizing influence during cooling through the transformation temperature range, promotes pearlite formation and, because of its austenite stabilizing influence, refines the pearlite.
3) Copper is a powerful hardener of the ferrite phase, which is the main phase representing over 80 per cent in weight.

These structural effects must necessarily correspond to an overall increase in hardness and strength of the alloy without creating hard spots, and without a material reduction in machinability. Moreover, it may also be anticipated that copper additions will result in an important decrease in the so adverse section sensitivity of gray cast iron. To what extent these various structural effects may improve the physical properties must be determined experimentally.

## II. EXPERIMENTAL RESULTS

In earlier literature dealing with the influence of copper additions on the physical properties of gray cast iron some contradictory results are reported, and even contradictory conclusions are drawn. However, this is not surprising as many investigators have tried to study the influence of copper by comparing irons of different origin and even different analysis, or even different casting sections.

A good and almost complete review on the effects of copper on the properties of gray cast iron appears in the publication *Copper as an alloying Element in Steel and Cast Iron* by C. H. Lorig and R. R. Adams.[8] The experimental results reported by these investigators are those from almost identical irons, except for the copper content. Such results are readily comparable and, if experimental conditions were kept constant, as is practically certain in the cases referred to, they may be considered reliable.

The results reported by C. H. Lorig and R. R. Adams show that copper increases tensile strength, transverse strength and Brinell hardness, but lowers deflection. The beneficial effect of copper additions on strength and hardness properties is proved up to copper contents of 3-3.5 per cent, which corresponds to the "practical solubility" of copper in gray cast iron.

More recently these conclusions of C. H. Lorig and R. R. Adams have been confirmed by A. de Sy and J. Foulon,[5] who studied the influence of copper on the basis of 140 experimental melts carefully controlled under laboratory conditions. Phosphorus and sulfur were kept constant while copper, carbon and silicon varied between the extreme limits:

Cu : 0 to 4.8%
C : 2.76 to 3.53%
Si : 1.48 to 2.04%

Manganese was kept at 0.50 per cent in one series and at 0.90 per cent in the other series.

The numerous values of the tensile strength determinations have been used in a broad statistical study, the results of which appear in Fig. 10.

Thus, it clearly appears that tensile strength increases with copper content up to approximately 3 per cent. The same conclusion applies for transverse strength and Brinell hardness.

### Experimental Verification of Quantitative Influence of Copper on Gray Cast Iron Physical Properties

In recent experiments at the author's laboratory, the quantitative influence of copper additions to gray cast iron has been checked once more, and this time with the maximum possible accuracy.

In order to study the specific influence of copper, identical charges, except of course for Cu content and corresponding balanced Si content, of accurately constant raw materials were melted in a high frequency induction furnace according to a normal and constant melting procedure, and cast at constant temperature in 1¼-in. and ⅝-in. diameter test bars.

Tensile strength and Brinell hardness values were

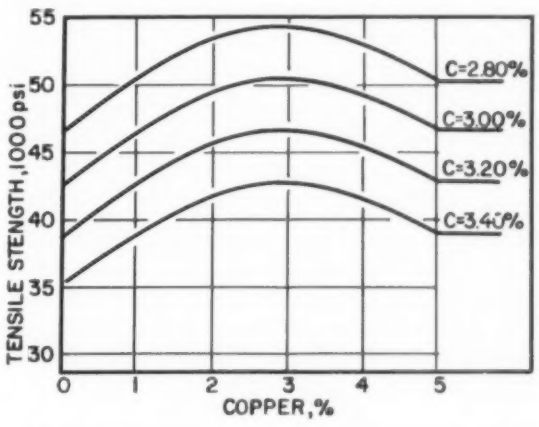



Fig. 10 — Tensile strength vs. copper content for different amounts of carbon. Test bar — ¾-in. diameter, as-cast. Si — 1.8 to 2.0%; Mn — 0.50%; P < 0.10%.

TABLE 1 — RESULTS OF TENSILE STRENGTH AND BRINELL HARDNESS TESTS

| Melt No. | Composition, % C | Mn | Si | Cu | Ni | S | P | Brinell Hardness 1¼-in. dia. | Brinell Hardness ⅝-in. dia. | Tensile strength, 1000 psi | Chill depth, mm | 20 mm Impact, kgm, |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S-11 | 3.20 | 0.9 | 1.86 | — | — | 0.065 | 0.10 | 187 | 246 | 39.0 | 13 | 2.5 |
| | | | | | | | | 181 | 234 | 39.0 | | 2.6 |
| | | | | | | | | 187 | 222 | | | |
| | | | | | | | | av. 185 | av. 234 | av. 39.0 | | av. 2.55 |
| S-13 | 3.16 | 0.88 | 1.75 | 0.50 | — | 0.065 | 0.10 | 200 | 257 | 39.9 | 12 | 2.7 |
| | | | | | | | | 198 | 257 | 42.4 | | 2.3 |
| | | | | | | | | 195 | 256 | | | 2.3 |
| | | | | | | | | av. 198 | av. 257 | av. 41.2 | | av. 2.43 |
| S-14 | 3.16 | 0.90 | 1.60 | 0.91 | — | 0.065 | 0.10 | 205 | 255 | 42.3 | 10 | 2.4 |
| | | | | | | | | 198 | 263 | 42.2 | | 2.2 |
| | | | | | | | | 210 | 262 | | | 2.4 |
| | | | | | | | | av. 204 | av. 260 | av. 42.3 | | av. 2.33 |
| S-15 | 3.19 | 0.91 | 1.54 | 1.93 | — | 0.065 | 0.10 | 224 | 281 | 44.7 | 5 | 2.2 |
| | | | | | | | | 219 | 278 | 45.1 | | 2.0 |
| | | | | | | | | 214 | 268 | | | 2.0 |
| | | | | | | | | av. 219 | av. 275 | av. 44.9 | | av. 2.07 |
| S-16 | 3.17 | 0.89 | 1.35 | 2.96 | — | 0.065 | 0.10 | 229 | 270 | 46.0 | 4 | 2.0 |
| | | | | | | | | 227 | 263 | 46.0 | | 2.2 |
| | | | | | | | | 231 | 265 | | | 2.0 |
| | | | | | | | | av. 229 | av. 266 | av. 46.0 | | av. 2.07 |
| S-17 | 3.15 | 0.88 | 1.52 | — | 1.82 | 0.065 | 0.10 | 207 | 260 | 42.9 | 9 | 2.4 |
| | | | | | | | | 204 | 253 | 43.9 | | 2.3 |
| | | | | | | | | 207 | 246 | | | 2.2 |
| | | | | | | | | av. 206 | av. 255 | av. 43.4 | | av. 2.30 |

determined according to the recommendations of the ISO/TC 25 Committee. Chill depth was measured on the Le Thomas test piece, and impact strength was determined by the Charpy method on a 20-mm diameter unnotched test piece with 100-mm distance between supports.

The results of this investigation are shown in Table 1.

From the description of the experimental procedure, and from the results of the chemical analysis of the different melts, it appears that the experimental accuracy is largely sufficient to permit drawing valuable conclusions as to the quantitative influence of copper additions on the physical properties of gray cast iron.

For this medium carbon iron cast in 1¼-in. diameter cylindrical bars, Brinell hardness increases by 20 units from 0 to 1 per cent, and by another 20 units from 1 to 3 per cent Cu. Likewise, the tensile strength shows an average increase of more than 2000 psi/per cent Cu, the increase also being greatest for the first per cent copper addition. It is further worth while stating that the hardness and strength values increase even more rapidly for higher carbon contents, although these results are not reported in this paper. The impact strength decreases moderately with increasing copper contents as previously reported by A. de Sy and J. Foulon.[10]

In conclusion, the experimental results shown in Table 1 agree with those reported by C. H. Lorig and R. R. Adams,[8] and also with those of the author's previous experimental research work.

Because copper is a powerful ferrite hardener, and also a powerful anti-ferritizer as explained in the theoretical part of this paper, it may logically be expected that copper additions will also substantially increase hardness and strength properties in heavy sections.

## Beneficial Effect of Copper in Heavy Section Castings

The increase in hardness, as well as the increase in uniformity of hardness distribution, has been reported by R. H. McCarroll and J. L. McCloud[9] on iron of constant Si content and variable Cu content cast in pyramid-shaped castings. One should, however, compare irons of different Cu contents but with constant carbon equivalent. This has been done at the author's laboratory by keeping total carbon constant and varying the Si content in order to balance it against the Cu contents. The carbon content chosen was 3.20 ± 0.03 per cent, and all melts with a carbon content out of this range (C analyzed on a chilled sample) were eliminated.

The carbon contents, together with the results of a complete analysis (except P which is: 0.05-0.07 per cent), are shown in Table 2. Extreme carbon limits are thus 3.19 and 3.23 per cent.

Meltings were done in a high frequency induction furnace under constant metallurgical conditions with the same raw materials, and the pouring temperature was also kept constant at 2460 F. Two test bars 1¼-in. diameter, and one cylindrical bar of 7 in. x 12 in. were cast from each melt.

The mechanical properties were determined as recommended by the ISO/TC 25 Committee, employing the diabolo-shaped, or type A tensile test piece, machined from the 1¼-in. diameter test bars and from test bars extracted from the 7 in. cylindrical bar, as shown in Fig. 11. The complete results of the mechanical tests are shown in Table 2, in which all Brinell hardness figures are the averages of 4 determinations.

TABLE 2 — CARBON CONTENT AND COMPOSITION ANALYSES FOR TEST BARS

| Melt | Composition, % | | | | | | | | 7 in. dia. Bar | | | | | | | | | | 1¼-in. dia. Bar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Tensile strength, 1000 psi | | | | | Brinell Hardness, $H_B$ | | | | | TS, 1000 | |
| No. | C | Si | Mn | Cu | Ni | Cr | Mo | S | o | m | c | m | o | o | m | c | m | o | psi | $H_B$ |
| 1 | 3.22 | 1.66 | 0.82 | 0 | 0 | 0 | 0 | 0.065 | 28.3 | 23.9 | 22.7 | 24.4 | 29.6 | 164 | 163 | 156 | 165 | 167 | 40.7 | 193 |
| 2 | 3.19 | 1.49 | 0.78 | 0.94 | 0 | 0 | 0 | 0.064 | 31.0 | 26.0 | 24.4 | 25.9 | 33.0 | 167 | 167 | 171 | 167 | 168 | 42.3 | 211 |
| 3 | 3.20 | 1.39 | 0.82 | 1.48 | 0 | 0 | 0 | 0.067 | 33.0 | 28.3 | 27.3 | 28.6 | 33.5 | 186 | 181 | 178 | 180 | 186 | 46.9 | 225 |
| 4 | 3.21 | 1.28 | 0.82 | 2.02 | 0 | 0 | 0 | 0.065 | 32.8 | 28.1 | 26.9 | 28.3 | 33.7 | 184 | 178 | 178 | 179 | 186 | 44.5 | 224 |
| 5 | 3.20 | 1.24 | 0.81 | 2.03 | 0 | 0.23 | 0 | 0.063 | 37.3 | 32.7 | 29.6 | 31.8 | 36.9 | 198 | 196 | 194 | 195 | 194 | 46.5 | 229 |
| 6 | 3.24 | 1.27 | 0.82 | 2.02 | 0 | 0 | 0.24 | 0.064 | 36.9 | 30.6 | 27.4 | 31.3 | 38.0 | 190 | 182 | 182 | 183 | 191 | 47.4 | 232 |
| 7 | 3.22 | 1.32 | 0.83 | 2.04 | 0 | 0.25 | 0.24 | 0.064 | 40.4 | 34.2 | 31.0 | 34.0 | 38.7 | 210 | 199 | 195 | 197 | 208 | 50.1 | 253 |
| 8 | 3.22 | 1.19 | 0.82 | 0 | 1.93 | 0 | 0 | 0.065 | 29.4 | 25.7 | 24.4 | 25.7 | 29.4 | 170 | 166 | 165 | 167 | 174 | 42.8 | 213 |
| 9 | 3.23 | 1.19 | 0.82 | 0 | 1.93 | 0.24 | 0 | 0.064 | 32.7 | 28.4 | 26.6 | 27.3 | 32.8 | 180 | 176 | 172 | 174 | 180 | 46.3 | 224 |
| 10 | 3.23 | 1.17 | 0.83 | 0 | 1.95 | 0 | 0.23 | 0.063 | 32.5 | 26.7 | 26.3 | 26.2 | 32.3 | 178 | 168 | 169 | 164 | 176 | 46.2 | 241 |
| 11 | 3.23 | 1.16 | 0.86 | 0 | 1.96 | 0.23 | 0.23 | 0.067 | 39.7 | 34.0 | 31.7 | 33.7 | 39.5 | 198 | 188 | 187 | 183 | 195 | 54.0 | 253 |

In comparing the results from melts 1 to 4, it appears that tensile strength and hardness increase regularly with increasing copper content. Considering the properties in the 1¼-in. diameter test bar, Brinell hardness increases by 30 points, and tensile strength approximately 4500 psi in passing from 0 to 2 per cent Cu, all other possible influencing factors being kept constant. These results confirm those of the first experiments shown in Table 1.

More interesting are the results obtained in the heavy section castings. Here again, when Cu passes from 0 to 2 per cent Brinell hardness is increased by 20 points and tensile strength by approximately 4500 psi. Moreover, the hardness is uniform over the section, with only a few points variation (lower) in the central part.

### Hardness vs. Casting Section

A good general survey of the influence of copper on hardness increase, and uniform hardness in thick sections, is given in Fig. 12. Figure 12 shows hardness values of melts 1 to 7 plotted against casting section. The same figure also shows the influence of supplementary additions of either 0.25 per cent Cr or 0.25 per cent Mo, or both (Cr and Mo additions are without correction of the carbon equivalent, melts 5, 6, 7 and 9, 10, 11).

A remarkable composition is that of melt 5. The hardness in the heavy section is almost perfectly uniform and high, nearly 200 Brinell. The alloy addition of 2 per cent Cu combined with 0.25 per cent Cr is believed beneficial for uniform high mechanical properties combined with good machinability, because of the absence of hard spots if chromium is limited to 0.3 per cent maximum. To the author's knowledge this alloy addition is applied successfully for diesel-engine cylinder liners.

Melts 8, 9, 10 and 11 almost exactly duplicate melts 4, 5, 6 and 7, but with nickel instead of copper, the carbon equivalent being maintained constant by lowering the silicon contents.

Table 2 and Fig. 13 show the comparative results of copper and nickel additions. Copper gives distinctly better results than nickel, especially in heavy section castings where hardness is not only high but also uniform.

The comparative results of the strength properties of copper and nickel alloyed irons cast in a thin and a heavy section are shown in Fig. 14.

## CONCLUSIONS

Because copper is a graphitizer at the solidification stage, and an anti-ferritizer on cooling through the transformation range, copper additions to gray cast iron prevent chilling in thin sections and free-ferrite formation in heavy sections. Thus, copper additions impart a uniform structure with neither hard nor soft spots, and at the same time remarkable overall strength and hardness properties.

This is a unique advantage in relation to machinability and wear resistance, which are both important for many of the practical applications and the engineering properties of gray iron castings.

Moreover, compared with other alloying elements whose influence is far from being so beneficial in relation to the most important engineering properties of gray cast iron, copper is a relatively inexpensive alloying element.

Therefore, it is difficult to understand why copper additions to gray cast iron are not used more extensively (this remark applies especially to Europe

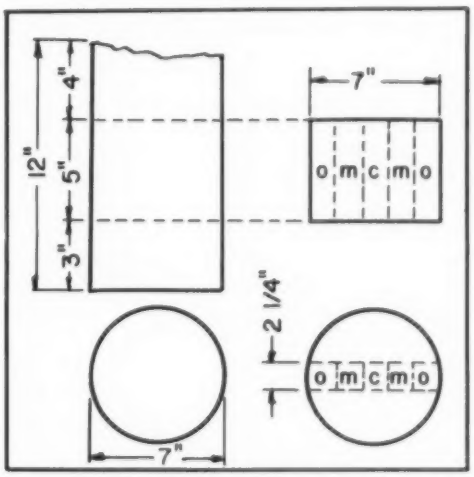



Fig. 11 — Method of extraction of test bars for tensile strength and Brinell hardness determinations from cylindrical bar 7x12 in.

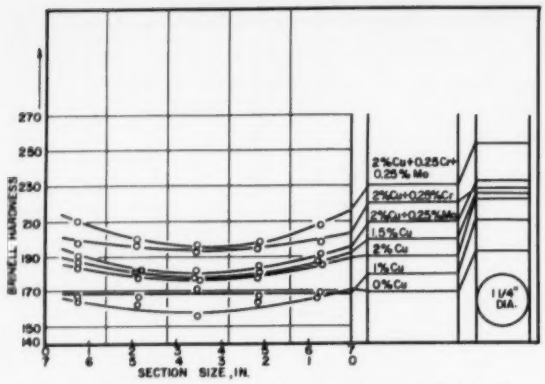



Fig. 12 — Copper effect on hardness increase and hardness uniformity in heavy section gray iron castings.

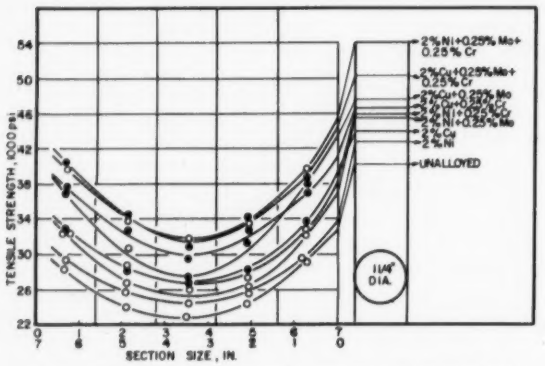



Fig. 14. — Comparative tensile strengths of copper and nickel alloyed cast irons in heavy and thin sections.

where, till recently, copper additions were practically unknown in the gray iron foundries).

At present, many foundrymen are beginning to make use of the important possibilities of quality improvement through copper additions to cast iron. Those foundries using this method which are known by the author obtain excellent results, not only from the metal quality point of view, but also from the castings quality point of view because of better density (absence of porosity) and soundness.

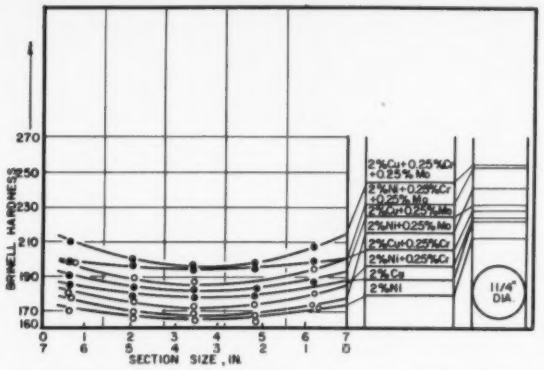



Fig. 13 — Comparative effect of copper and nickel on hardness increase and hardness uniformity in heavy section gray iron castings.

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# NEW FOUNDRY RESINS AND APPLICATION TECHNIQUES FOR SHELL MOLDS AND SHELL CORES

By William C. Capehart

## ABSTRACT

**Resins used in the foundry shell mold or shell core processes are either of the pulverized or liquid type. These are applied by the dry blending and coating processes. The operational problems which are encountered when using shell molds and shell cores are peel back or drop off, poor casting finish, caking of coated sand and thermal cracking. Corrective measures can be taken to overcome these difficulties. Control tests on the resin-sand mix assure the uniformity of the mixes used in production. Tensile strength, flexural strength, melt point, cure rate and pickup test are used.**

## INTRODUCTION

The use of resin products in foundry technology has become an accepted casting tool. Last year U.S. foundries used an estimated 12-14 million lb of resins in the production of shell molds and shell cores. Most observers expect the 1959 total to go considerably higher. Hand in hand with this growth has come the rapid development of improved resins and improved application techniques. It seems worth while to examine some of the more recent advances to see how the ferrous and non-ferrous foundry may derive the most benefit.

## RESINS

Resins are conveniently classified in two broad groups—"thermoplastic" and "thermosetting." Thermoplastics may be softened by heat and then harden into shape upon cooling. This process can be repeated almost indefinitely, as these plastics undergo physical and not chemical changes. Thermoplastic resins include such natural products as wood rosin, and synthetics such as polystyrene, polyethylene and polyvinyl chloride. The thermosetting types will harden or set into a permanent shape when heat is applied and undergo physical as well as chemical changes; thus, the process is irreversible.

Thermosetting resins include such products as phenol-formaldehyde, urea-formaldehyde, epoxies, polyester and melamine-formaldehyde. The resins used in the foundry today are combinations of chemicals reacted to form long chains of molecules linked together with little if any branching or crosslinking or partially cross-linked polymer chains, both of which form a three dimensional network design upon cure. Resins melt with heat and then cure to form a rigid bond between the sand grains.

The phenol-formaldehyde resins are used most often. Such resins are of two classes; "one stage" and "two stage." The one-stage type is made with a specifically designed phenol and formaldehyde ratio, and reacted in the presence of a catalyst. The resin as discharged from the kettle is thermosetting or heat reactive and requires only further heat to complete the reaction to an infusible, insoluble state. These resins are used for conventional core binders and some hot coating operations.

The two-stage type also is made with phenol and formaldehyde reacted in the presence of a catalyst. However, the specific ratio of ingredients are reacted such that upon discharge from the kettle they have formed a linear thermoplastic type polymer commonly called a "novolak." To produce a thermosetting resin, additional formaldehyde and heat must be added. Formaldehyde is usually furnished by the breakdown of such a material as hexa-methylenetetramine ("Hexa") when heat is applied. These resins are stable in storage even when pulverized with the hexa or placed in alcohol or solvent solutions.

### Two-Stage Resin

The foundry trade is familiar with the pulverized resin compound made up of a two-stage phenolic resin and hexamethylenetetramine and used in dry powder blend shell mold operations. Continued research effort has enabled the resin supplier to select a range of resin physical properties which give consistent performance and eliminate most of the shell production problems. As an example, the flow and cure of a dry powder blend type resin can be selected as critical properties.

With too long a flow and a slow cure resin, the resin-sand mix tensile strength is low, the shell and core pickup is fast and peeling is encountered. With a medium flow and a slow cure resin, the resin-sand mix tensile strength is good, the shell and core pickup is medium and usually no peeling will result. With a short flow and slow cure resin, the resin-sand mix tensile strength is low, the shell and core pickup is slow and delamination peeling may be encountered. With a long flow and fast cure resin, the resin-sand mix tensile strength is low, the shell and core pickup is low and delamination peeling may result.

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With a medium flow and fast cure resin, the resin-sand mix tensile strength is good, the shell and core pickup is medium and some delamination peeling may be encountered. With a short flow and fast cure resin, the resin-sand mix tensile strength will be low, the shell and core pickup is slow and delamination peeling may result. These relationships formed the basis for many of the present day dry powder resins. There are exceptions to the above rules of thumb brought about primarily by the demand for higher production rates and other resin considerations.

### Coating Resins

Both one-stage and two-stage phenolic resins are used for shell molding, shell cores and as bases for coating resins. There are several types of coating resins, such as alcohol solutions of novolak resins, powdered novolaks blended with hexa and wax for use with alcohol and water, crushed lump novolaks, water borne novolaks and one stage resins.

Alcohol solutions of novolak resins, usually in the 60-80 per cent solids range, are one of the most prominent coating resin forms. These resins require the addition of hexa and wax during the coating cycle. Liquid-type resins are attractive because they offer such benefits as bulk handling and metering, a lack of resin loss by dust during mixing and with a very efficient use of the resin and in handling the coated sand, the resin film has good resistance to abrasion from the sand.

The powdered novolaks containing hexa and wax are used with alcohol and water solvent systems for coating in what is commonly called alcoholic deposition. These have such benefits as controlled hexa, wax and resin ratio weighed as one unit, volumetric use of solvents and possibly 1-2 min faster coating cycle than liquids.

Most of the foundrymen are well acquainted with the types of phenolic resins just discussed. A new addition to the coating resins field, however, is the novolak or two-stage resin supplied as a rough crushed lump to be melted on hot sand. Considerable research work has been done to arrive at a resin which melts readily to give controllable mixing properties and have adequate tensile and hot casting strength.

These resins require the use of hexa and wax during the coating cycle. Lump resins have such qualities as a fast coating cycle, nonflammable solvents and little, if any, caking of the coated sand.

### Water-Borne Casting Resins

Another new type of system is the recently developed water borne coating resins. These are divided into two classes. The first is the one stage resin which requires no crosslinking agents such as hexa, but react rapidly when heated. However, in some cases, hexa is used to speed up resin coating and cure. These resins are usually stored under refrigeration between production and use to extend their life.

In the coating process they are mixed to the desired melt point and tensile strength properties with heat, and the coated sand cooled rapidly for good control of these properties. Some of the benefits of the one-stage resins are; a fast cure, and a nonflammable solvent system.

The careful controls in storage, mixing and handling of the resin and coated sand made with the one-stage type resins has made the idea of a novolak resin in a stable water system attractive. These resins, as do all novolaks, require the addition of hexa, usually a powdered or dissolved form and a wax as desired. These stable water borne novolaks are desirable because of the nonflammable solvent system.

Water borne novolaks may be used with hot sand or hot air and have a fast coating cycle. The coated sand is nonblocking and stores easily, and a versatile range of resin properties is available to meet varied production requirements. There is no resin storage problem, and preliminary indications are that they are more resistant to thermal cracking than other types of coating resins.

In the use of coating resins, the relationship of various resin physical properties and the coated sand performance is similar to those of a dry blend powdered-type resin. The relationships are easily noticed in the hot coating process where the resin characteristics are changed during coating. These changes are manifest by such resin-sand mix tests as melt point, tensile strength, flexural strength, rate of cure and pickup thickness.

With two-stage resins some empirical relationships have become evident such as; when the coated sand melt point is raised, the tensile strength and flexural strength is lowered and the shell or core pickup thickness is less. At certain high melt point levels, a delamination peeling condition can be incurred. This is brought about because the resin flow is shortened and the resin cure is faster. When the coated sand melt point is lowered, the tensile strength and flexural strength is raised and the shell or core pickup thickness is increased. This is due to the resin flow being lengthened and the cure being slower.

Also, when the bake time (cure cycle) of a shell or core is lengthened, the tensile strength and flexural strength increases at a fairly rapid rate and reaches a maximum after which the resin degrades reducing the tensile strength and flexural strength. These relationships point up the importance of processing the resin to reach optimum performance characteristics for production conditions.

### Cold or Warm Coating Resins

In cold or warm coating-type resins, the same relationships hold as for hot coating resins. However, since the resin characteristics are not changed during the coating process, the supplier provides resins of various properties to fit a wide range of desired shell or core operating conditions. There are exceptions to these general empirical relationships discussed, and illustrated in Fig. 1, because many different types of resins are made and new developments are anticipated in resins, coating processes and machinery for processing and shell and core production.

## RESIN APPLICATION TECHNIQUES

Each foundry must select the resin that is the most economical and gives the best castings for its operation and, therefore, should study resins in light of present requirements and future outlook.

The application technique of resin in shell molding or shell cores has changed considerably in the past several years, and in coating one might say in the past few months. The dry powder blending with a powdered resin compound was the original method of dispersing the bond and still is continued profitably in many foundries. As the sand companies learned more about shell molding, they have produced special sands which have reduced the resin content needed for dry blending to a more economical level.

The wide acceptance of the dry powder blend technique is evident because no special equipment is required that is not already in the foundry, and it is fairly foolproof once a study has been made to determine the time necessary for efficient resin dispersion. Due to the simplicity of this technique, the foundry just entering the shell mold field finds that it eliminates one of the problems in consistent shell production at a time when new process problems are at their greatest.

The resin properties available cover a wide range of shell applications. Dry resins have a tendency to dust, but a number of satisfactory dust suppressants are available.

The foundryman's desires to produce more complicated castings in shell, get higher production rates, to improve his working conditions and to use blowing techniques for shells as well as cores, have given rise to the coated sand procedures. Various techniques have evolved starting with a conventional powdered shell resin and a solvent, and progressing to special resins for each coating technique.

## Methods of Coating Sand

There are three broad methods of coating sand which involve the placement of resin on each sand grain. These methods are classed as cold, warm and hot. Cold coating entails the use of room temperature sand and room temperature air. Cold coating can be performed in most conventional foundry mixing equipment except for cement or cone blenders. Alcohol solutions of novolaks and powdered resin compounds used with alcohol and water will perform well with this method.

The typical coating procedure for a liquid resin calls for catalyst and lubricant placement in the mixer and dry blended 10-20 sec with the sand. Then the resin is added and the mixture blended until it is wet. At this time the room temperature air is fed in. As mixing is continued, the resin-sand mix becomes a doughy mass called a ball stage. With continued mixing and solvent evaporation this dries out and breaks down. The time to reach dryness depends upon the amount and type of resin used, the mixer, and the type of sand.

Use of a powdered resin with a solvent requires a similar operation, except that the dry blending of the resin and sand takes 30 sec to 2 min for adequate resin dispersion. Then the solvent is added and mulled until the mix is wet. From this point the operation is the same. Some of the reasons for cold coating in addition to the regular coated sand benefits are; limited capital investment and fewer mixing variables to control.

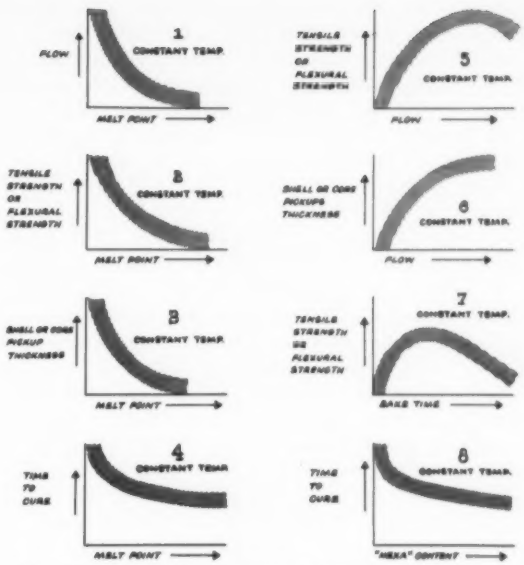


Fig. 1 — Conventional two-stage phenolic resin physical and empirical relationships.

Warm coating usually involves the same type of mixing equipment as for cold coating, but a modification has to be added to circulate warm air up to about 225 F through the muller. Air up to 450 F may be used for short periods provided the resin is not advanced appreciably. The degree of advancement or change can be measured in terms of such tests as melt point, tensile strength and flexural strength. The same types of resins and procedures used in cold coating apply to warm coating.

A short cooling cycle may be required to arrive at about room temperature coated sand before use or storage. Warm coating has the added benefits of reducing the cold coating mix cycle, increasing the coating capacity over cold coating because of less ball stage and producing less caking of the coated sand. In the cold and warm coating processes there is essentially no change in resin characteristics during the coating operation, as only the solvent has been removed leaving a resin film on the sand.

## Hot Coating Sand

Hot coating involves the three basic techniques of much hotter air or hotter sand, or both. In hot coating, the resin is advanced and its characteristics are changed substantially with heat (220-500 F). A measure of the change is noticed by the melt point rise when samples are taken at various time intervals during coating. This enables the foundry to have one resin perform on many different types of molds or patterns simply by selecting the desired resin advancement to give optimum performance.

One method of hot coating employs sand at room temperature and hot air. After a short blending of the catalyst and lubricant, the liquid novolak resin or a water borne resin is added. When the resin has wet the sand, hot air is fed in until the desired resin melt point is reached at which time a water quench may be used for cooling purposes. With additional

mixing, the water stops resin advancement and breaks down the ball stage for easier handling.

Another method involves the use of hot sand at 225-400 F, and water borne resins or crushed novolak lumps. The water borne mix follows a cycle in which resin is added to the hot sand and mixed to wetness. Next, the hexa and lubricant are added and mixing continued until the desired resin properties are reached. At this time a water quench may be used for cooling purposes, and to stop resin advancement and break down the ball stage for easier screening.

In the use of a crushed lump novolak, resin is added to hot sand and mixed until it melts and coats the sand. A water-hexa quench is added to stop volatile resin removal and give minimum resin advancement. After cooling, the lubricant is added in the mixer if not originally introduced with the lump.

Another method employs the use of hot sand and hot air with the three resins mentioned above. These various techniques may be altered to meet individual needs in order to secure better control or meet machinery operating requirements.

These hot coating processes have such benefits as a fast mix cycle, little, if any, caking of the coated sand in storage, nonflammable solvents when water borne or lump novolaks are used, a hard resin film that is resistant to abrasion from the sand in handling and the opportunity to tailor the resin properties to meet a wide range of shell mold or core conditions.

Each foundry must study the various resin application techniques in light of economy, performance, as well as present and future requirements.

## BOND VARIABLES

In coating sand, as in any bonding process, there are several variables which influence the bond strength. The first consideration is the sand used. The round grain sands have less surface area than subangular sands and need less resin for comparable strengths. However, round grain sands may cause more thermal cracks than sharp sands due to grain expansion rates in casting certain type metals.

The finer sand grains give more surface area for resin to cover and requires higher resin contents. Although finer sands give smoother finishes on castings, to conserve resin each foundry should use the coarsest sand possible to produce the desired finish. In some cases coarse sands may be offenders in resin abrasion from coated sand during the mixing and give erratic coating results.

Clean sand, which is low in organics and clay, require less resin. Also, organics, clays and oxides found in some sands give a cushioning effect on certain type castings to reduce thermal cracking. Therefore, a blend of two sands or the use of additives sometimes is desirable.

The bond in resin-sand mixes is developed between resin films on the sand, and, in turn, resin to sand. Thus, it is apparent that wetability of the sand grain by resin, and the bond between resin and sand, is important. Therefore, sands which have thin films of such things as clay, carbon or alkalies, may give poor strength and consequently, low strength mixes.

In the introduction of any new process, there are some variables and problems encountered which demand a solution in order to have consistent production. Efficient production depends upon the foundryman's ability to determine the source of trouble and arrive at a solution in a reasonable time. It may be of interest to define some typical problems and discuss possible causes and corrective measures.

## SHELL MOLD AND SHELL CORE OPERATIONAL PROBLEMS

### Peel Back or Drop Off

Peel back occurs when a shell mold or shell core pulls away from the pattern or mold face at certain sections, usually around the edge or on projections. The sections which have pulled away from the pattern lay back on the mold and remain attached to shell or core. Drop off occurs when parts or all of the shell or core completely falls from the pattern or box. This may also occur as chunk drop off. Possible causes and corrective measures are:

1) *Resin Sand Mix Improperly Made.* Check ingredient amounts and mixing procedure. If the mixer is used for other foundry cores be sure it is free of core oils. Run at least two to three cleanout batches.
2) *Wet Sand.* With the moisture above 1 per cent, sand will blend or coat poorly and retain part of the water. The cure will be slowed down so the shell will not stay on the pattern. Use dry sand below 0.5 per cent moisture. With the hot sand technique a wet sand may be used and dried as it is heated.
3) *Pattern or Core Box Temperature too High.* When the temperatures of patterns or box are too high, they cause a buildup of extra thick shells or cores which may peel or drop off because of the heavy weight. To correct this, lower the mold temperature and/or speed up the investment cycle.
4) *Pattern or Core Box Temperature too Low.* When pattern temperatures are too low, the shell or core may not be cured sufficiently to stay in place after the roll over. To overcome this condition increase the mold temperature or preheat the mold.
5) *Dwell Time too Long.* With long dwell time, the shell or core may build up too thick and peel or drop off the pattern or mold. Decreasing the dwell time gives a thinner shell or core.
6) *Sticking to Side of Dump Box.* The sides of the dump box at the pattern contact point may get hot and cause sticking and peel around the edges. Silicone rubber and/or a water jacket around this location will eliminate the problem. Also, pattern border outlines will give a clean break.
7) *Not Enough Mix in Dump Box.* Small amounts of mix in the dump box give poor compaction, and high projections will peel or drop off. A heavy-burden drop and good coverage eliminates this condition.
8) *Solvent Not Removed From Coated Sand Sufficiently.* Solvents remaining in the coated mix may give off gas which results in slow cure and

peeling or drop off. To correct this, screen and aerate more effectively or adjust the coating cycle.

9) *Pattern or Core Box Design.* Patterns with high projections which cause large temperature variations tend to cause peeling. Insert heaters or special heating relieves this. Aluminum patterns of certain design may lose heat rapidly to cause peeling. Dissimilar pattern materials may cause peeling or sticking. Consider pattern heating problems when designing patterns.

10) *Resin Content of Mix too High or too Low.* High resin content may cause too heavy a build-up on the pattern or mold and produce peeling. Too low a resin content produces weak shells or cores which peel or drop off.

**Poor Casting Finish — Rough Surface**

1) *Resin Sand Mix Improperly Made.* Improperly coated or blended sand may have resin rich lumps and give poor fillout of shells or cores. The fine grain sand may be lost as small lumps when the coated mix is screened, and, therefore, give rough surface finish.

2) *Sand with Large Amounts of Coarse Screen Material.* The casting finish is dependent upon the sand grain size used in the core or shell. The finer sands give smoother finishes but require more resin.

3) *Pattern or Core Box Temperatures too High.* High pattern or core box temperatures overcure the shell or core and may produce washes or sand inclusions due to a weakened shell or core. Use a constant temperature that gives consistently cured shells or cores.

4) *Too Little Resin in Mix.* Low resin content tends to cause washes, out of dimension products, cracking and metal runouts.

5) *Turbulent Metal Flow, or Lack of Effective Choke Feeding.* To produce castings with smooth surfaces, more devices must be used to assure smooth metal flow and adequate fill of the cavity. Metal pouring range and fluidity of the metal determine the shell rigging. Most metals take on a better finish if pouring is on the cool side.

6) *Poor Resin Mix Application to Pattern or Mold.* Poor fillout of cores is the result of unsuitable blowing pressure, venting and sand flowability. Poor fillout in shells comes from light drop of mix, air trapped by resin-sand mix as it falls over the pattern or slow drop of mix. Adjust blowing pressure and vents to each mold. Add more mix to the dump box, vent the pattern area and speed up box roll-over. Use a vibrator on the box or mold to increase the density and remove trapped air.

7) *Hard Pouring of the Mold.* Pour steadily enough for good fill but not too hard to cause metal turbulences, aspiration or excessive head pressure in the cavity.

8) *Poor Shell Bonding.* Bond wherever possible on the shell to prevent formation of fins, cope floating or strains. Use as many springs as possible on the glue press over the bonding area. Bond while the shell is hot. Its temperature should be at least 275-375 F. Each bonding resin has an optimum shell temperature for assembly. Bond before the glue sets up onto a thick bond, preventing mold closure and causing fins. The liquid-type bonding resins or slurries do a good job when used properly.

**Caking of Coated Sand**

This refers to the formation of lumps, hard balls or a solid mass a short time after the coated sand is discharged from the coating mixer. It is usually caused by residual solvent or heat.

1) *Poor Solvent Removal.* Screen and aerate the mix until no green strength is present, or adjust the mix cycle or conditions.

2) *High Humidity Day.* On high humidity days solvent removal is more difficult and may require more aeration than is needed in less humid weather. Gradual solvent reduction is recommended when powdered coating resins are used. This problem is more prevalent in cold or warm coating processes.

3) *Resin Reacted by Heat.* Long mixing cycles in warm coating may overheat the coated sand and partially cure the resin-sand mix. Warm coated sand temperatures above 170 F may cause trouble. The inclusion of a cooling cycle in mixing or proper aeration after screening will relieve this problem.

4) *Hot Storage.* Hot storage area, or failure to reduce hot coated sand below 140-160 F, can tackify the resin and induce caking.

5) *Resin Sand Mix not made Properly.* Review the coating procedure and be sure of ingredient amounts.

6) *Wet Sand or Excess Quench Water.* Excess moisture in sand is extremely hard to remove in cold or warm coating and can make the resin sticky and lumpy. If excess quench water is used in hot coating this should be reduced gradually. Moisture may be condensed on the coated sand during handling, so check at various points to determine this location.

7) *High Clay Content of Sand.* High clay content makes solvent difficult to remove and can result in solvent caking.

8) *High Sand Fines.* Sand fines form small lumps which may retain solvent and cause caking.

9) *Excessive Additives.* Excessive additives such as plasticizers or green strength additives cause caking in storage or processing.

10) *Hot Air Turned on too Soon.* In warm coating, hot air may cause encasing of the solvent by a resin film. As this solvent percolates through, it produces caking. To correct this condition, adjust the mix cycle or reduce the air temperature.

**Thermal Cracking of Molds or Cores**

Most shells crack at many places as the binder burns out. However, the metal has usually solidified sufficiently to prevent run-outs. Thermal cracks usually occur less than 25 sec after the metal has been poured, and may give metal run-outs or casting fins. Thermal cracks in most cases come at stress points in

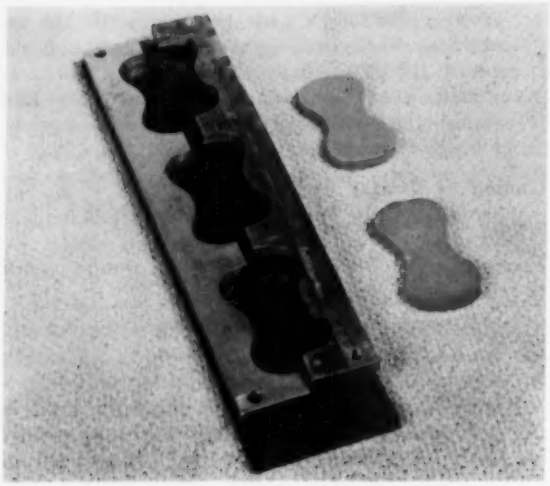

**Fig. 2 — Tensile strength control test for resin-sand mixes utilizes the standard AFS recommended ¼-in. briquette. After the mix has been placed in the 400 ± 10 F mold, the strike-off is made in both directions from the center of the longitudinal axis.**

the shell. Possible causes and corrective measures for this condition are:

1) *High Resin Content.* With excess resin the shell or core cures to a rigid, brittle form that is prone to crack. To eliminate this reduce the resin content or undercure the shell or core.
2) *Sand Segregation.* When coarse sands are encountered by segregation using a high resin content, the shells or cores become rigid and brittle. If there is an excess of sand fines, the mix becomes weak and cracks easily. Periodically, sample the sand and run a screen analysis. Sands with four or five screen distribution have proved more resistant to thermal cracks than two or three screen sands.
3) *Overcured Shells or Cores.* Overcured shells or cores are rigid, brittle and may be weak. Control pattern and oven temperatures to minimize the overcure.
4) *Improper Shell Assembly.* Poor placement of the shell bonding resin may produce weak bond areas and cracks. Misaligned bonding machine pins set up stress areas that are relieved with pouring. Shells may become too rigid or cold before bonding, causing stress areas or cracks and a weak bond. High air pressure on the bonder may crack or stress the shells.
5) *Warped Shells or Cores.* Warped shells or cores set up concentrated stress areas. Here again, pouring relieves this stress. Determine the cause of warpage and take corrective action.
6) *High Ferro-Static Pressure.* Hard pouring and unsupported shells may cause cracking. Pour only hard enough to get good fill. Bed the shell or give as much support as possible to prevent cracking of the shell by weight stress.
7) *Geometric Stress Cracks.* Some casting shapes are especially likely to produce stress areas in the shell. Elimination of as many sharp corners as possible helps prevent cracks. Also, notching shells in certain places forces the cracks into less critical areas. In some shells, reinforcing rods or ribs prevent or at least limit cracks. Specially designed shell flasks or frames promote even rates of expansion and eliminate cracks or reduce them to a point at which the cracks do not produce out-of-dimension castings or fins.
8) *Cold Shells.* On certain types of castings and metals cold shells may cause thermal cracks. Pouring the shells while they are warm or torching them before pouring reduces this problem.

## CONTROLS FOR RESIN-SAND MIXES

A new foundry process calls for some means of control to insure uniform production. The resin supplier uses such physical properties as melt point, flow, cure, solids content and viscosity as his control criteria for each batch of resin. Rigid specifications must be met before a shipment is made. The resin suppliers are conscious of the responsibility of product uniformity to the customer.

There are several tests which can be performed on the resin-sand mixture that do not require elaborate equipment but relate to production conditions. Such tests make it possible to compare various binders, to check the uniformity of mixes and the influence of mechanical and raw material variables. Many foundries use as many as five of these control measurements. Some of these are tensile strength, flexural strength, melt point or stick point, cure rate and pickup.

### Tensile Strength

This test utilizes the standard AFS recommended ¼-in. briquette (Fig. 2). After the mix has been placed in the 400 ± 10 F mold, the strike-off is made in both directions from the center of the longitudinal axis. Care should be taken to get as smooth a surface as possible in the strike-off, and also to prevent chatter which results in uneven specimen density. The specimens are cured in an oven at 580 ± 10 F for 2 min.

Cure time must be adjusted for the type and amount of resin used, and for the blend or coating process so as to develop the maximum tensile values. Coated sand usually cures faster than dry blends. The specimen can also be made by blowing techniques and cured in the same general way.

Any suitable tester may be used to break the specimens once they have cooled to room temperature. It has been found that results often vary as much as ± 15 psi between operators. Therefore, in establishing a control range for mixes this must be taken into account. The weight of the specimens indicates mix density and flowability, and relates to tensile strength. The value of the test is limited, and must be used only as a relative comparison because the values are small, because of operator variation and because of jaw failures.

### Flexural Strength

The specimen mold may be fabricated from aluminum or other suitable metal, such as cold rolled steel (Fig. 3). The molding mixture may be taken

from a production batch or compounded in the laboratory in any efficient mixer. Conditions for molding are chosen to conform approximately with those of the shell or core producing machine. The practice has been to use a mold temperature of 400 ± 10 F, and a cure time of 2 min at 580 ± 10 F.

The test pieces are molded by filling the mold cavities to overflow, then striking off the excess quickly with a metal straight edge. After the pieces are cured for 2 min, its dimensions are about 5 in. x ½-in. x ½-in. One side of the specimen is rough and non-uniform. Since the flexural strength is dependent greatly upon the uniformity of the cross-sectional area, the rough side is abraded to produce a constant thickness.

This is done by passing it under an abrasive wheel with set clearance. Each piece is then cut in half to produce two bars each about 2.5 in. x 0.5 in. x 0.33 in.

The bars are tested in any suitable device for the measurement of flexural strengths. It is important that the same face (rough or smooth) be in the same position for all tests.

The test has good reproductibility.

### Melt Point or Stick Point Test

This test is used for coated sand, but is not recommended for resin-sand dry mixes. Although the resins are amorphous and have no true melting point, they do soften as heat is applied. The temperature at which the resin film on the coated sand mix softens sufficiently to adhere to a plate is recorded as the melt point. A ground steel bar (11¾ x 2⅜ x 10⅛ in.) may be heated to provide a temperature gradient by means of two 50 watt, 115 V, bayonet heaters. Two holes are drilled in one end of the bar to receive the heaters. A temperature gradient of 125-250 F is obtained by incorporating a power reostat in the system (Fig. 4).

To determine the melt point or stick point, the resin coated sand is spread to a depth of about 1/16-in. After allowing 1 min to elapse starting at the cooler end the coated sand is brushed lightly off with a camel hair brush, or may be blown off with low pressure air at a constant distance of the nozzle above the bar. The temperature of the section on the bar at which the coated sand sticks is measured with a pyrometer.

This temperature is the melt or stick point. Typical satisfactory values for core mixes vary from about 160-210 F, while values for shell mold mixes vary from about 180-230 F.

This is a fast test for determining the quality of each batch before using it in production. The test is particularly valuable in hot coating. Each resin has a melt point range in which it performs best for shells or cores. Higher than normal melt points indicate resin abrasion from the sand, or too much resin advancement. Lower than normal melt points indicate excess resin, unremoved solvent, or under-advanced resin. The melt point in hot coating is a time and temperature relationship and must be adjusted with one or the other to arrive at control values.

### Cure Rate or Depth of Cure Test

An empirical comparison of cure rate can be made by reducing the cure time of a standard AFS tensile briquette and breaking it while hot. The nearer the tensile strength value approaches the maximum tensile of the specimen as run on a regular test, the faster the resin cure rate. A second method consists of dumping or blowing the coated sand into a heated conical mold and base plate at 450 ± 10 F (Fig. 5). The excess is struck off, and the specimen and mold are placed in an oven at 580 ± 10 F and baked 30 sec.

The mold and specimen are brought from the oven and the specimen ejected. This specimen is cut in half, top to bottom, and the uncured mix removed from the interior leaving a cured outer shell. The cured thickness is measured to determine the rate of resin cure or depth of cure. The thicker the section, the faster the cure.

### Pickup Test

Into a heated cylinder and base plate at 450 ± 10 F, the resin mix is dumped or blown (Fig. 6). The mix

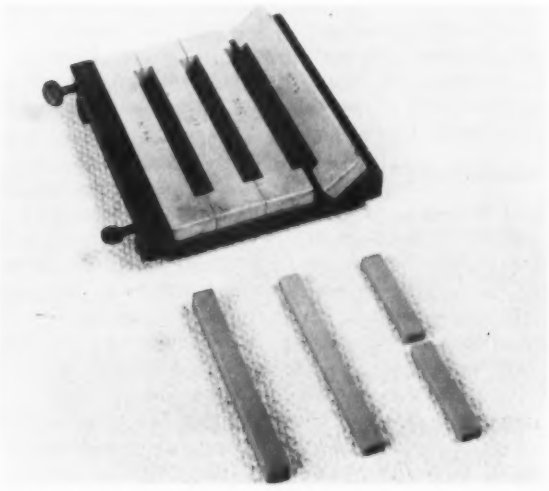

Fig. 3 — In the flexural strength test for resin-sand mixes the specimen mold may be fabricated from aluminum or other suitable metal such as cold rolled steel. Conditions for molding are chosen to conform approximately with those of the shell or core producing machine.

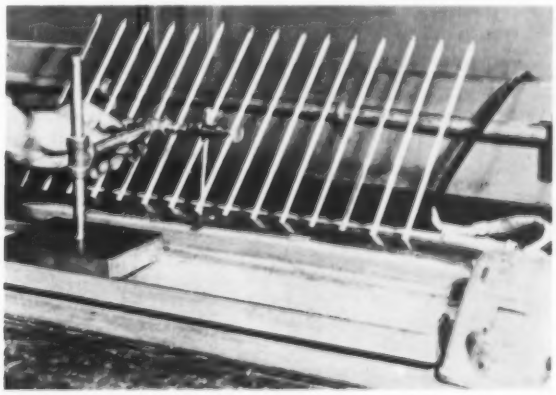

Fig. 4 — The melt point or stick point test is used for coated sand. Two holes are drilled in one end of the bar to receive heaters. The temperature gradient of 125-250 F can be obtained.

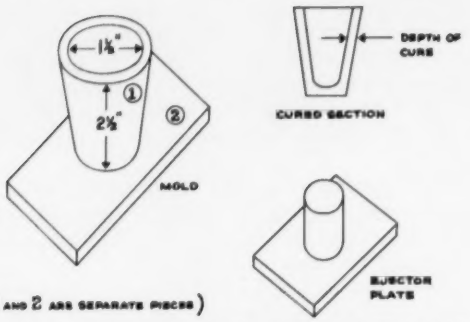


Fig. 5 — In the rate or depth of cure test illustrated the coated sand is dumped or blown into a heated conical mold and base plate at 450 ± 10 F. The excess is struck off and the specimen and mold are placed in an oven at 580 ± 10 F and baked 30 sec.

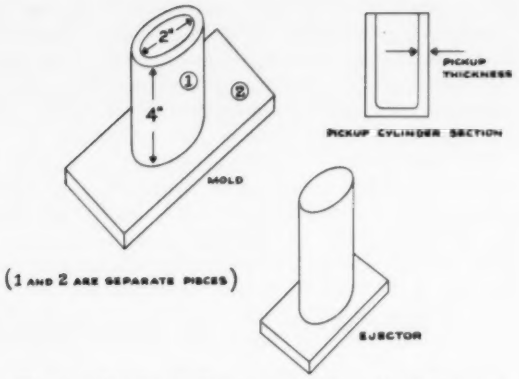


Fig. 6 — In the shell core or shell mold pickup test the resin mix is dumped or blown into a heated cylinder and base plate at 450 ± 10 F, and invested for 15 sec, and cured in an oven at 580 ± 10 F about 2 min after which the cylinder is ejected from the mold and cooled for weighing.

is invested for 15 sec and the excess is dumped. The specimen and mold are placed in an oven at 580 ± 10 F and cured about 2 min, after which the cylinder is ejected from the mold and cooled for weighing. Afterward, it may be cut in half to determine the wall thickness. This determines the investment time required, resin content or temperature needed to secure a specified wall thickness. This test also checks mix flowability and density of the mix.

There are other valuable tests such as hot deformation, expansion, peeling, hot deflection, scratch hardness, collapsibility and resin content by loss on ignition. Such tests may be of value at particular foundries where certain problems exist or a preference is indicated.

## Summary

The resins used in the foundry shell mold or shell core processes are of two physical forms. These are the pulverized and liquid types. The pulverized resin forms are resin compounds and crushed lump novolaks. The liquid resin forms are alcohol solutions of novolaks, water borne solvent systems of novolaks and water borne solvent systems of one-stage resins.

The resin application techniques are dry blending and coating. The coating processes are cold, warm and hot, dependent upon the method used to place a resin film on each sand grain and degree of resin advancement. The newer coating types involve the use of hot sand or hot air or combinations of these.

Some factors that influence the resin sand bond quality are sand grain shape, grain size and contaminants.

Some typical problems in shell mold and shell core production are peel back or drop off, poor casting finish, caking of coated sand and thermal cracking. These may be encountered in using dry blends or coated sand, and corrective measures can be taken.

Control tests on the resin-sand mix such as tensile strength, flexural strength, melt point, cure rate and pickup, assure uniform mixes.

Production of satisfactory castings using shell molds and shell cores depends upon an understanding of the resins being used, the most economical resin application technique, the ability to analyze a production problem swiftly and a knowledge of proper corrective measures as well as the establishment of suitable controls to insure consistent day to day operation. Great strides have been made in all these fields, and the future holds even more rewards for the aggressively managed foundry.

## ACKNOWLEDGMENT

The author wishes to thank the Monsanto Chemical Co. for permission to publish this material. He also expresses his gratitude to Messrs. B. Freedman, C. Elmer, G. P. Harris and H. Sandman for aid in accumulation of these data and constructive criticism of the subject matter.

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# THE FOUNDRY PLANT ENGINEER

## *a fifty year reminiscence*

By James Thomson


### ABSTRACT

**Often, it is really worth while to take a backward look over the past to get a proper perspective of where we now stand and perhaps where we are headed. Not necessarily that we should be "proud of the good old days," but that we may have a better appreciation of progress made.**


### INTRODUCTION

In retrospect, let us take a brief look at the foundry industry in the early years of the present century. There were many foundries in this country—iron, steel and non-ferrous, a few large and many small, but to a great extent there was little or no mechanization. Production was mainly by manual labor. True, in some foundries there were cranes, some belt conveyors, air tools, etc., but they were more or less the exception. And this was also true in other industries. In fact, mass production, as developed by the automobile industry, had its inception in the first decade of this century.

### MASS PRODUCTION ERA

For the past three or four decades American industry has been traveling along in what might be termed the "Mass Production Era." The methods, principles, organization, research, etc., developed by the automotive industry have been studied and adapted by other industries including our own, which have resulted in a tremendous increase in the productive capacity of the country. Accompanying this change in our industrial history has come a myriad of inventions, machines, equipment, materials, methods, etc. Even our educational system has been affected by it.

At the turn of the century there were few, if any, men who might be termed foundry plant engineers. In fact, I doubt if the title was even known those days. Engineers seemed to have an idea, which in many instances was true, that foundries were dirty and unpleasant places in which to work, and many did not seem to be interested. In fact, my introduction to the subject was an illustration of that attitude.

I was working on the drafting board in the design engineering department of a large machine concern. One day the Chief Engineer stopped at the board of an engineer and said, "Bill, the superintendent of our steel foundry wants a man to make a plant layout for him, and I should like you to go up and take care of it for him." Bill replied, "Chief, I would like to be excused; I don't want to work in a dirty foundry." The Chief then turned to me and asked if I had heard the conversation. I had, so he asked me if I would like to take the assignment which he guessed would take about three or four weeks.

After discussion and arrangements I told him "Yes, I should like to get some first hand knowledge of foundry work," figuring that it would be of value later in the design work we were doing.

So on the next Monday morning I arrived at the steel foundry, and the superintendent turned me over to the master mechanic who was to direct me in what was wanted.

### PLANT LAYOUT

The job they wanted was a scaled layout or map of the plant buildings, and the main items of equipment therein. Some small amount of information was in the form of sketches and prints in the desk drawers and on books in the master mechanic's office which, by the way, was in the engine room of the power house, not partitioned off, just a desk and drafting board in the engine room. The remaining data had to be obtained in the field.

A couple of weeks went by and I was getting information for the map, and absorbing what I could of operations in the foundry. One day the master mechanic asked me to lay aside the layout temporarily and make some drawings for him of parts he needed to get some equipment in shape. Later there were other interferences caused by drawings needed for other things, so the three weeks job extended to three months. My chief kept asking when I would be finished at the foundry.

About this time the superintendent approached me with the proposition that he would like to have me stay with the foundry as a sort of engineering assistant to the master mechanic. He said he was convinced that the foundry needed some sort of engineering approach to some of their problems, and thought that I might fill the bill.

### ATTITUDES DEVELOPED

By this time I had developed two strong attitudes, first an intense interest in the operation of that steel foundry, and second a tremendous regard for the knowledge and ability of the master mechanic. He

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was Swedish, probably thirty years my senior, a mechanic of the old school with wonderful ability and resourcefulness. I was intrigued with the idea of working with him and trying to absorb some of his knowledge and qualifications.

So I agreed to take the job if a transfer could be obtained from my chief. This then was my inception as a foundry plant engineer. The proposed original stay of three weeks lasted for ten years with that company.

As I look back over these ten years, I am somewhat amazed at the variety of experiences and opportunities which occurred. I developed into a sort of general utility man in the plant. There were, of course, the engineering jobs in collaboration with the master mechanic and the general office, such as building extensions, installation and relocation of equipment, design of special equipment, improvement of existing equipment, maintenance problems, etc. However, I sometimes got pushed into the operating departments. The superintendent would call up and say that "so and so foreman is sick (or going on vacation), will you look after his work until he returns."

Thus, I was permitted to get some acquaintance with operating problems.

## PRODUCT INSPECTION

One day the plant manager called me to his office and he and the superintendent discussed with me the fact that they had never had any definite inspection of the product. What was my opinion? My reply was that I was surprised that they had not established a definite inspection program long ago. They agreed that I was right, and said that such a program was about to be started. I remarked that the inspector they appointed would have a battle on his hands, and should be responsible only to the management. They agreed and much to my surprise told me I was "it."

So the inspection department was established and, although it was a battle for a while, the quality of the finished product improved. Complaints from customers became fewer and fewer and eventually all agreed that it was a valuable addition to our operations.

One interesting problem during this period was an investigation of our power plant. In those days, central power was not as common as today, hence many plants had their own boiler and engine rooms. We had three 250 hp boilers, two engines directly connected to D.C. generators, two air compressors and various auxiliaries. Our investigation led to a vast improvement in efficiency in the power plant, and the collecting of data which proved to the company the need for additional equipment. This comprised a mixed pressure turbine-driven generator, a large compressor and auxiliary equipment.

I shall not weary you with a recital of figures about our increased efficiency, but it was outstanding enough so that our superintendent bragged about it to the other plant managers of the company. The company at that time had six plants, five of which had foundries. This led to my being loaned to these other plants for work in their power plants, and eventually to a job during my last two years with the company, in charge of power plant operations of all the plants.

Many of the problems in this work were personnel rather than equipment problems, and many incidents both sad and humorous might be told about them. For instance an old German fireman at one of the plants seemed to object to my interference with his work. He said "I can wheel more coal than any fireman in Allegheny County, and no young whippersnapper of an engineer is going to tell me how to do my job."

I replied, "Pete, the more coal you wheel to these boilers, the more ash you have to wheel out. Look at you, your face, and hands and clothes are black from so much coal and ash handling. You don't have a minute's time to rest and wash up. If I can show you how to keep up steam with less coal, wouldn't you be happy?" Pete replied, "But you can't. I've been firing these boilers for 15 years and you can't show me." Well we showed him and he was really happy, and we saved many tons of coal.

That was over 40 years ago. No doubt many changes have taken place in these plants, one of which would be a change to central station power.

In the ten years I have been talking about I received a wonderful apprenticeship in foundry plant engineering, and had come to the conclusion that there is a field of work in the foundry industry for plant engineers.

## FOUNDRY ENGINEERING

One day I received a call from a man who had been manager of the above steel foundry during part of my time there, and who had left to become president of a foundry company in the middle west. He asked me to meet him in Pittsburgh. He had an interesting but discouraging tale to tell me about his plant. They could not get production problems licked because of serious mechanical and electrical breakdowns. Would I be interested in visiting the plant and considering the job of plant engineer.

To say the least, I was flattered to think that my old boss thought enough of my ability that he would call on me for help in his trouble. I therefore agreed to spend a couple of days in the plant, and would advise him later of my decision.

My visit at the plant indicated to me that the story the president had told me was undoubtedly true. The plant was far from being as well equipped as the one I was thinking about leaving. The prospect did not look inviting. So I did a lot of thinking about it. Maybe it was even worse than I had observed. Would I get proper backing from the management? Would I get along with the production departments? What kind of maintenance personnel and equipment were available? Had I the guts to fight it through against the difficulties which would arise, etc. etc?

In my dilemma I decided to talk it over with my old friend the master mechanic. After explaining the situation to him he said, "Jim, I advise you to take the job. I know it will be hard but is a great challenge and I am sure you can handle it. Here is an

opportunity to further prove your theory that plant engineers are needed in the foundry industry."

I finally decided to make the move after getting a clear understanding as to my authority, who was to be my boss, that the maintenance department was to report only to me, etc.

But what an awakening! It was far worse than had been anticipated. The plant was started in 1910, and this was 1916, and it looked like they had failed to properly maintain it. There were little or no records of equipment, practically no spare parts, no idea of preventive maintenance, few maintenance tools and machines (and these inadequately equipped) and maintenance personnel was rather poor and underpaid. As an example, they had two cranes which were identical, but instead of getting repair parts for both, one was shoved into a corner and was being robbed of parts to keep the other going.

The storeroom keeper used his ideas of what kind of materials should be bought for the maintenance department, such as oils, bearing metals and electrical materials, instead of buying what the master mechanic ordered.

What a mess I had gotten into! The master mechanic told me that when I visited the plant the manager had purposely prevented me from talking to him alone, and that if he had told me about the conditions I probably would not have come.

To say the least it was a terrible disappointment. Not only from the plant conditions, but the production department seemed to think that this "new broom" was going to quickly sweep away a lot of their troubles. However, that was impossible, and I was often the goat for things that affected production.

These experiences taught me an important lesson. Knowledge, experience and personality were not the only faculties needed. One had to add to these that important qualification—intestinal fortitude. We were in a struggle to build a better operating plant and, therefore, had to fight it through against all odds.

I might recite many incidents of this period, some almost unbelievable and some humorous, but suffice it to say that day by day and month by month things began to look up.

## NEW BUILDINGS

The first world war was on and we were in it. We had to build another foundry to satisfy government demands. New buildings and equipment had to be planned and installed. These were interesting days for the plant engineering and maintenance departments. With improved and enlarged personnel and organization we were able to carry out the construction program in good shape. The demands of wartime production developed many additional problems for these departments.

Eventually the war was over and we had to resume commercial production. About this time I began to see here and there that a few foundry companies had seen the value of having a plant engineer in their organization. This made me happy, knowing that now these companies were beginning to realize the value of the engineering approach to many of their problems.

It is true that there were some engineering concerns which did some consulting work on foundry problems, but even when they were employed it became evident that when the foundry company had their own plant engineering department there existed a better means of contact with the consultants. For here were men who talked the same language and could discuss the problems from a similar background.

## INDUSTRY DEVELOPMENT

The next two decades after the first world war showed a remarkable development in the foundry industry. Many new ideas showed up and much new equipment was developed. New equipment and materials companies sprung up. And may I be bold enough to assert that in the development of much of this new or improved equipment foundry plant engineers played a prominent part, even if some of the producers may not agree. Our demand for better construction, better lubrication, better dust protection, better controls and a myriad of other suggestions has made the equipment much better than it might otherwise have been.

During this period there also developed a great interest in the idea of preventive maintenance. Much has been written and discussed on this subject, and much progress has been made in some places. However, there is still much more to be accomplished.

## ADDITIONAL FACILITIES

In the middle of the twenties our company was finally convinced that a machine shop for large work would be an excellent addition to the facilities. This problem was turned over to me. It was interesting not only from the standpoint of building design, machine tools and equipment, but from the fact that I had often to oppose some of the suggestions of my superiors. For instance I turned "thumbs down" on two of the locations for the new shop they suggested. I told them that they were not looking far enough into the future and that their locations prevented extensive enough enlargment.

This has been proved true as the shop has been extended until it now is over five times its original size. It is perhaps the largest miscellaneous machine shop in the middle west. Complete steel rolling mills can be produced in it.

In 1930 our company expanded by taking over two other foundry and machine companies in the East. We then had four plants. To me was assigned the job of Chief Works Engineer for all the plants. This of course added much larger responsibilities, so we organized for it by having a plant engineer for each of the divisions and located at his own plant. Thus, I had a contact man at each plant who could carry out his assignments for that plant.

Of course, you all remember the terrible days of the depression of the thirties. Most of our plans had to be laid aside. Yours truly was the complete works engineering department. He was chief engineer, blue print boy, draftsman, estimator, etc., but happy to have a job. However, things eventually got better and we gradually got back to normal.

Then we were faced with the Second World War and the foundry industry was called on to do a tremendous job. The war work assigned to our company required the expansion of our present facilities and the erection of two new plants. This was handled under the planning and superintendence of our Works Engineering Department. After the war, of course, we were faced with the many problems connected with the getting back into commercial production, and the Works Engineering Department had its share of these problems.

## CONCLUSION

This then is a sort of rambling story of my connection with foundry plant engineering and I should like to conclude with the following remarks:

It has been a wonderfully satisfying and pleasing experience to watch the development of the foundry industry during these 50 years.

I am happy to note the wide acceptance among foundry companies of the idea of the "plant engineer," and to see this additional field of work which has been opened to engineers.

I am particularly pleased to note the fine work being accomplished by the Foundry Educational Foundation in interesting college students to study the cast metals industry, and, thus, provide a supply of educated men to fill important places in our industry.

Last but by no means least, I must congratulate the American Foundrymen's Society for the fine work it is doing for the industry through its Headquarters Office, Chapter Organization, officers, committee members, paper authors and others. It is constantly supplying its members and the industry with valuable information, and telling the world at large the importance of the foundry industry.

# DUCTILE IRON PRODUCTION IN BASIC DIRECT-ARC FURNACE

By C. R. Isleib

## ABSTRACT

**Addition alloy cost savings, less reladling and a reduced tendency toward drossing are advantages gained by using a basic-lined direct-arc electric furnace for the production of ductile iron. The use of a basic desulfurizing slag during meltdown upgrades the base iron and preconditions it for the making of ductile iron at low magnesium residuals.**

## INTRODUCTION

Electric melting furnaces are used in many foundries today, with well-known advantages. They are becoming a part of more and more shops, either alone or as part of a duplexing operation. They steadily become more attractive costwise as electricity tends to become a comparatively cheaper source of power for melting. Atomic power generated electricity may encourage this tendency in the future.

The electric furnace can melt any kind of a scrap charge. The holding time in the furnace, and the temperatures attained, can be varied at the will of the operator. A basic-lined direct-arc electric furnace can operate with a great variety of oxidizing or reducing slags.

The production of spheroidal graphite magnesium-containing iron, commonly known as ductile iron, first of all requires almost complete desulfurization of the base iron melt. This is done either before the magnesium addition or as part of the magnesium addition. It can be done through the use of slags.

In basic electric steel practice, slags have been used for over 40 years for both oxidation and reduction of undesirable impurities. Generally, elements other than sulfur are first oxidized with a lime-iron oxide slag. Then the steel is desulfurized and deoxidized under a reducing lime-fluorspar slag.

The first published work on refining iron in a basic electric furnace, and then treating it to produce ductile iron, is that of Hignett.[1] Hignett desulfurized a molten iron bath by using a lime slag, plunged 0.2 per cent calcium metal into the desulfurized bath, and then treated the iron by adding magnesium and postinoculated it with ferrosilicon. At 0.026 per cent residual magnesium and over, a fully spheroidal structure resulted. These heats were on a small laboratory scale. These results were confirmed and commercial possibilities suggested by three tests in 1952, using a larger direct-arc furnace.

Fully spheroidal irons were produced at about 0.024 per cent magnesium. Further work was needed to define some of the reaction rates, limits of composition and properties of the product.

Since 1941 there has been much basic investigation of the principles of desulfurization of iron and steel, a great deal of it by Chipman and associates.[2] Complete and rapid desulfurization has been found to depend upon the basicity of the slag and the effectiveness of the slag-metal contact, and also upon the slag temperature and the oxygen potential of the slag in those furnaces operating under reducing conditions. Slag basicity in blast furnaces and electric furnaces is sometimes measured by adding the molar concentrations of the basic oxides, calcium oxide (CaO) and magnesium oxide (MgO), and subtracting from this the molar concentrations of the acid compounds.

A slag's oxygen potential is a measure of its iron oxide (FeO) content. Further, investigators have shown that additions of silicon dioxide ($SiO_2$) or manganese oxide (MnO) to slag interfere with the desulfurization reaction.

Sulfur in steels usually is not required to be brought below 0.02 per cent, but for making ductile iron lower sulfur content is desirable. A low sulfur base iron is in the best condition to react to a minimum magnesium addition.

Chipman explains that the basic desulfurizing reaction in a reducing furnace is:

CaO (in slag) + S (in metal) + C (in slag) = CaS (in slag) + CO (gas).

At equilibrium the minimum "S (in metal)" is theoretically 0.001 per cent. This served as a theoretical target for desulfurization.

## EQUIPMENT AND PROCEDURE

The furnace used in this work is a basic-lined, three-phase, direct-arc furnace. It has a rammed magnesite bottom, magnesite brick sidewalls and a top of mullite shapes. It is capable of melting up to a 750-lb charge. Preheating for about 50 min by arcing onto crossed electrode ends in the bottom of the furnace preceded each heat. A few pounds of slag materials were used around the electrodes during the beginning of the heat to encourage a smooth meltdown. As the metal pool increased, more slag was added. The aim was to have a maximum proportion of lime with just enough fluorspar to make the slag workable, so that it would cover the bath surface to a depth of about 1 in.

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This encouraged a high slag basicity. A late graphite addition was made to insure a carbidic slag low in iron oxide (FeO). Silica in the form of foundry sand adhering to charged metal was avoided. The furnace lining and the charges were dry, and the charging door was kept closed as much as possible. These precautions were meant to eliminate oxygen and hydrogen as far as possible.

The calcined ("burned") lime and fluorspar used in these heats had the analyses listed in Table 1.

All furnace charges analyzed less than 0.005 per cent magnesium, and about 0.035 per cent titanium.

## RESULTS

Table 2 is a summary of 11 experimental basic direct-arc furnace heats made, and the properties of the ductile irons produced.

### Desulfurization in the Furnace

Desulfurization of iron in a direct-arc electric furnace was simple. It involved little more melt time or work than necessary for an ordinary meltdown at the level of 0.02-0.05 per cent sulfur being charged. Slag equal to 3 to 4 per cent of the metal weight made a ½-in. to 1 in. thick layer of fairly foamy, fluid slag at 2800 to 2900 F. A ratio of 2 lime to 1 fluorspar, all sized below ½-in. mesh, was used. Six to 8 lb of the mix were used to help at the start of the meltdown. When about 2850 F was reached, a small amount of lime or fluorspar was used to bring the slag to the proper consistency.

TABLE 1 — SLAG MATERIALS ANALYSES

| Chemical Analysis, % | Burned Lime | Fluorspar | Dolomitic Burned Lime |
|---|---|---|---|
| CaO | 85 | | 57.3 |
| MgO | 13 | | 38.3 |
| S | 0.037 | 0.034 | 0.4 (as $SO_3$) |

Cold charges melted under this high calcium oxide lime-spar slag were desulfurized at 0.005 per cent sulfur or lower by the time they reached 2850 F. This was considered near the practical limit of desulfurization.

After the first three heats, an addition of graphite was made to the slag after meltdown. This was to insure the reducing conditions necessary for optimum desulfurization. After such an addition, quenched slag samples had a white-gray color and carbidic smell. This was used as an operating test.

Desulfurization of an already molten charge is also simple and quite fast. For example, the rate of desulfurization of a hot metal charge from about 0.024 per cent sulfur down to 0.004 per cent, is plotted in Fig. 1. A 250-lb cold charge had been melted down under 28 lb of lime-spar slag. A specimen taken for temperature and chemical analysis measured 3000 F, and analyzed 0.004 per cent sulfur. An addition of a 500 lb cupola tap measuring 2550 F, and analyzing 0.038 per cent sulfur, brought the total melt to 0.024 per cent sulfur and somewhat below 2600 F.

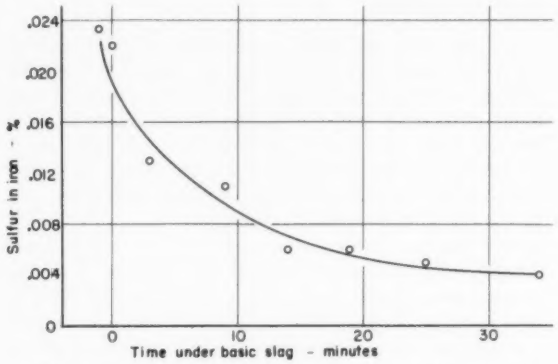


Fig. 1 — Rate of desulfurization of hot metal charge (heat 5) in the basic electric furnace.

TABLE 2 — PROPERTIES OF SOME IRONS MELTED IN THE DIRECT-ARC ELECTRIC FURNACE UNDER BASIC SLAGS

| Heat No. | Pre-magnesium Treatment | Mg Treatment Alloy | Mg Treatment % | Addition Method | Chemical Content, % T.C. | Si | Mn | Ni | Mg | Postinoculation Alloy | Physical Properties TS, psi | E, % | Bhn | Graphite in 1 in. DKB Sph., % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | None | Ni-Mg | 0.38 | on bath | 3.6 | 2.0 | (0.4) | (1.5) | 0.023 | 0.5% nisiloy | 105,500 | 9 | 241 | 90 |
| | | Ni-Mg | 0.30 | on bath | 3.6 | 2.0 | (0.4) | (1.5) | 0.021 | 0.5% nisiloy | 100,000 | 9½ | 237 | 92 |
| | | Ni-Mg | 0.30 | on bath | 3.6 | 2.0 | (0.4) | (1.5) | 0.032 | 0.5% nisiloy | 113,250 | 9 | 259 | 85 |
| | | Ni-Mg | 0.30 | on bath | 3.6 | 2.0 | (0.4) | (1.5) | 0.016 | 0.5% nisiloy | 68,200 | 2 | 215 | 80 |
| | | Ni-Mg | 0.30 | on bath | 3.6 | 2.0 | (0.4) | (1.5) | (0.018) | 0.5% nisiloy | 72,000 | ½ | 281 | 60 |
| 2 | None | MgFeSi | 3.34 | on bath | (3.6) | (2.0) | (0.4) | (1.5) | 0.019 | 0.5% nisiloy | 75,000 | 2½ | 228 | 85 |
| 4 | None | Ni-Mg | 0.65 | tap onto | 3.6 | 2.11 | (0.2) | (1.5) | 0.029 | 0.75% $Fe_{85}Si$ | 71,900<br>60,750 | 16½<br>26 | 181 | 90 |
| | | MgFeSi | 1.0 | tap onto | 3.6 | 2.84 | (0.2) | (1.5) | 0.031 | 0.75% $Fe_{85}Si$ | 74,500<br>67,200 | 17½<br>25 | 185 | 90 |
| 6 | CaSi+CaC Deoxidation | MgFeSi | 1.24 | tap onto | 3.5 | 2.45 | (0.4) | 1.18 | 0.013 | 0.6% $Fe_{85}Si$ | 47,400 | 0 | | 75 |
| | | MgFeSi | 1.61 | tap onto | 3.5 | 2.49 | (0.4) | 1.18 | 0.014 | 0.6% $Fe_{85}Si$ | 69,250 | 2 | 217 | 80 |
| 7 | CaSi+CaC Deoxidation | Ni-Mg | 1.13 | on bath | 3.6 | 2.18 | (0.4) | 2.31 | 0.049 | 0.6% $Fe_{85}Si$ | 106,500 | 3 | 277 | 95 |
| | | Measuring Burnout | | | 3.6 | (2.2) | (0.4) | (1.2) | 0.040 | 0.6% $Fe_{85}Si$ | 93,200 | 5 | 229 | 90 |
| | | Measuring Burnout | | | 3.6 | (2.2) | (0.4) | (1.2) | 0.023 | 0.6% $Fe_{85}Si$ | 93,400 | 1½ | 269 | 90 |
| 9 | CaSi Deoxidation | MgFeSi | 2.2 | tap onto | 3.56 | 2.45 | | 1.01 | 0.051 | 0.5% $Fe_{85}Si$ | 107,700 | 2½ | 293 | 90 |
| 10 | CaSi Deoxidation | MgFeSi | 2.2 | tap onto | 3.56 | 2.60 | | 0.26 | 0.058 | 0.5% $Fe_{85}Si$ | 111,250 | 4 | 293 | 97 |
| 11 | CaSi Deoxidation | MgFeSi | 2.2 | tap onto | 3.54 | 2.71 | | 0.31 | 0.084 | 0.5% $Fe_{85}Si$ | 102,600 | 4½ | 256 | 90 |

By the time 2650 F was reached, desulfurization had progressed to 0.006 per cent. Since desulfurization does proceed faster at high temperatures, if the cupola metal had been hotter it is probable that the desulfurization in the electric furnace would be even quicker.

### Base Irons Upgrading

Late additions of calcium silicon rabbled into the slag-covered heats, without any magnesium alloy addition, produced upgraded irons with tensile strengths up to 63,200 psi. This upgrading occurs because the late addition introduces small amounts of calcium and magnesium into the iron, partially spheroidizing the graphite. The log of one such heat is shown in Fig. 2. Late additions of calcium silicon were rabbled into the slag covered heats in all except the first four melts. These upgrading furnace treatments were done at practical working temperatures, below 2900 F.

Calcium carbide was also used as a furnace slag addition, but the evidence in Figs. 2 and 3 points to the calcium silicon as being a more effective agent in the pretreatment.

Besides upgrading the base irons, the late additions of calcium silicon to the desulfurized melts before magnesium treatment resulted in a more nearly fully spheroidal graphite ductile iron at lower magnesium residuals than without such an addition. Figure 7 shows that those heats having had a late calcium silicon addition before magnesium treatment, and then treated to between 0.01 per cent and 0.02 per cent residual magnesium, were consistently better in structure than those heats not having a calcium silicon slag addition.

### Dolomitic Lime Slags Use

Iron melted under a dolomitic (high magnesium oxide) lime slag had a greater tendency toward a spheroidal graphite structure before magnesium treatment than iron melted under a high calcium oxide lime slag. Figure 3 is the log of a dolomitic lime heat and can be compared with Fig. 2, a heat under a high calcium oxide lime slag. Reports had been received of a completely spheroidal graphite iron having been made in Europe under a dolomitic lime slag simply by reducing into the iron some of the magnesium in the slag. Under the dolomitic slag more magnesium and calcium were found in the iron, and the iron contained more graphite in spheroidal form.

### Magnesium Treatment Within the Furnace

After desulfurization, a small furnace addition of magnesium is sufficient to produce good quality ductile iron. Addition of ½ per cent of nickel-15 per cent magnesium alloy to a cleared spot on the bath's surface is adequate. Ferrosilicon postinoculation is done on tapout.

Furnace addition trials were made with the alloy wrapped in nickel foil, this package being tied on a steel rod and plunged beneath the bath's surface, thrown directly on the slag blanket or thrown onto a cleared space on the metal bath surface. The third method was little trouble and most practical. Magnesium ferrosilicon gave poor magnesium recovery when used as a furnace addition (below 10 per cent in all trials).

Figure 4 shows the magnesium recovery to be expected at various addition temperatures. For consistent recovery, bath temperature must be ascertained before treatment. This can be done by an immersion couple, or an optical reading during the tapping of a small ladle of iron. A reliable optical reading cannot be obtained directly in the furnace.

After the magnesium treatment the metal is tapped at about 2750 F, and a postinoculant is added to the tapping stream. Assuming the addition was ½ per cent of nickel-15 per cent magnesium alloy at 2750 F, the ductile iron then contains about 0.025 per cent magnesium, has little tendency to form dross and is at a good casting temperature.

Magnesium burns out of the iron in the furnace at a moderate rate provided the holding temperature is not too high and no arc is used. Holding at 2700 F about 0.001 per cent magnesium burns out per min; at 2800 F about 0.002 per cent per min. Figure 5 shows an average burnout rate over a range of temperature with the power off. If treated iron has to be held in the furnace for an extended time, booster additions of the magnesium alloy can be made to make up for the predictable burnout.

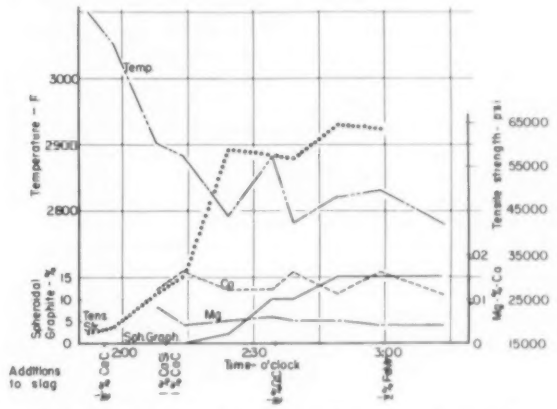


Fig. 2 — Log of heat 7, slag made using a high CaO lime.

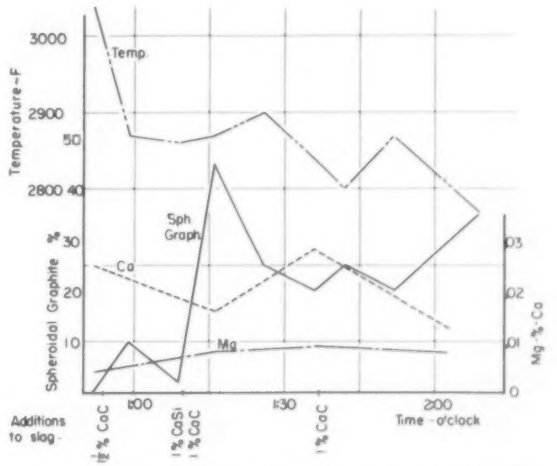


Fig. 3 — Log of heat 8, slag made using a high MgO lime.

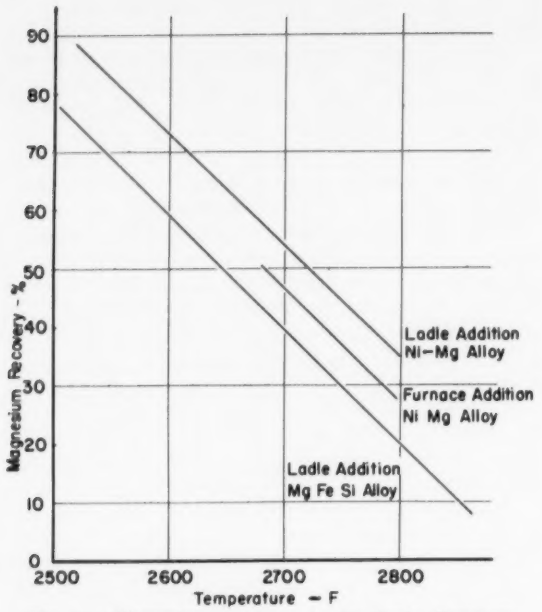


Fig. 4 — Magnesium recovery in the basic direct-arc furnace process.

Despite the degree to which these heats are preconditioned for magnesium treatment, they did not accept a raw magnesium metal addition with any composure. Trials were made during heat 8, plunging about 0.14 per cent bar magnesium into the melt in the furnace of 2750 F. Magnesium recovery was under 5 per cent.

### Magnesium Treatment on Tapout

After desulfurization a small magnesium addition to the tapout stream will also produce good quality ductile iron. This addition can be made at a higher temperature because of the greater magnesium recovery effected this way, as compared with an addition to the furnace. Figure 4 shows expected magnesium recoveries at various ladle treatment temperatures. Treatment temperatures must again be ascertained by an immersion couple or a small base tap. Any of the usual proprietary addition alloys are suitable, provided they give sufficient magnesium recovery at the desired addition temperature.

### Residual Magnesium Content

The graphite in these refined irons becomes well-spheroidized at unusually low magnesium residuals. Several typical structures at progressively greater magnesium residuals are shown in Figs. 6a-6c. Figure 7 summarizes the residual magnesium graphite spheroidization relationship for all the irons (only well-inoculated irons are considered in this relationship). The threshold value over which predominantly spheroidal graphite ductile irons were produced was about 0.021 per cent magnesium.

Aiming for 0.025 per cent residual magnesium, instead of a usual 0.055 per cent, producers equipped with basic electric melting units can cut magnesium alloy costs in half. Furthermore, because the producer would be treating a completely desulfurized iron, he would not need to add any magnesium alloy for desulfurization. This means further substantial savings.

### Dross in Castings

The incidence of dross (cope-surface defect) is greatly lessened in low-magnesium ductile irons. The casting shown in Fig. 8 is used at the authors company's laboratory to measure dross in ductile irons. The three horizontal projecting shelves are broken off, and a $\frac{1}{20}$-in. transparent grid is placed on the fracture. The total number of grid openings through which dross can be seen is counted, and the sum of the counts for the three shelves averaged. An average dross count of 270 is read when one of these standardized 0.07 per cent magnesium castings is poured starting with an 0.04 per cent sulfur charge in a neutral electric furnace. Figure 9 shows a moderately drossy fracture.

Compared with that average dross count, basic-melted irons show less than 15 per cent as much dross at magnesium levels below 0.04 per cent. Several tests are shown in Fig. 10.

## MECHANICAL PROPERTIES

### Tensile Properties

The tensile properties of refined low-magnesium ductile irons in the 0.02 to 0.03 per cent magnesium range are excellent. Table 2 lists a number of fully treated bars of varying analyses. The properties of these bars, ranging from 113,250 psi ultimate tensile strength and 9 per cent elongation with a pearlitic structure to 60,750 psi ultimate tensile strength and 26 per cent elongation with a ferritic

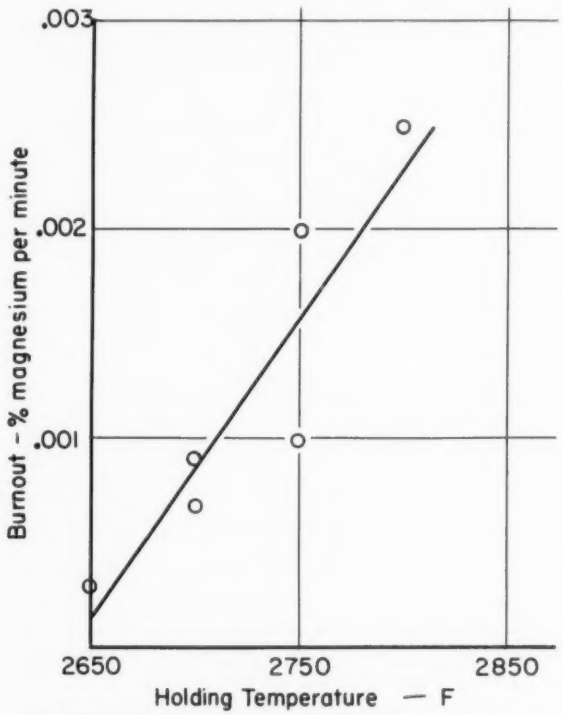


Fig. 5 — Burnout rate of magnesium in iron under a basic slag in the direct-arc electric furnace.

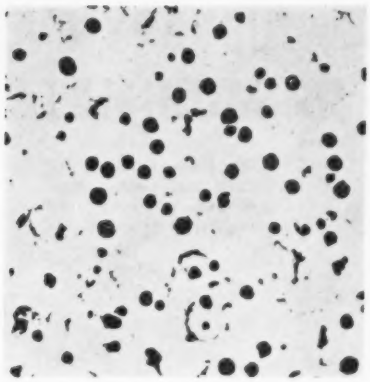

Fig. 6a — 47,000 psi tensile strength. 0 per cent elongation. 0.013 per cent magnesium.

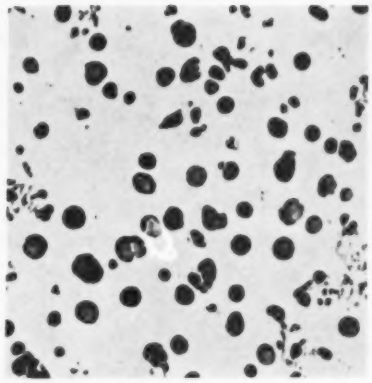

Fig. 6b — 68,200 psi tensile strength. 2 per cent elongation. 0.016 per cent magnesium.

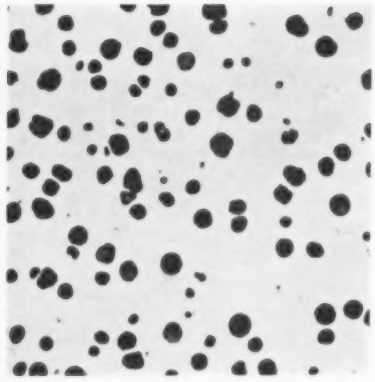

Fig. 6c — 100,000 psi ten. str. 9½ per cent elongation. 0.021 per cent magnesium.

Figs. 6a-6c — (left to right) Graphite structures of basic melted low magnesium irons as-cast 1 in. keel blocks. Unetched. 50 ×.

structure, compare favorably with average ductile iron tensile properties, Fig. 11.

Tests of several irons in the 0.01 to 0.02 per cent magnesium range are also included in Table 2. These irons contained more or less flake graphite, and their tensile properties do not match those of the fully spheroidal graphite iron with higher magnesium residuals.

The average ductile iron property range, shown in Fig. 11, has been useful in judging quality of pearlitic-ferritic ductile irons. It was developed by a statistical study of the tensile properties of 112 one-in. ductile iron keel bars containing 90 per cent or more spheroidal graphite. The range of chemical analyses included among these irons is: 3.4 to 3.9 per cent total carbon; 1.54 to 3.49 per cent silicon; 0.04 to 0.58 per cent manganese; 0.013 to 0.12 per cent phosphorus; 0.07 to 1.96 per cent nickel; and 0.021 to 0.13 per cent magnesium.

### Hardness

The chilling propensity of these low-magnesium basic furnace ductile irons seems no less than that of any other ductile irons similarly inoculated. In measurements of hardness of ⅛, ¼, ½ and 1-in. sections, an approximately comparable residual magnesium and carbon equivalent were made. They fail to show the basic furnace iron to be any softer than indirect arc furnace irons melted in a neutral furnace.

## CONCLUSIONS

1) Ductile iron can be consistently produced at 0.02 to 0.03 per cent residual magnesium using the basic-lined direct-arc furnace for melting. Deoxidizing the base metal by a late calcium-silicon addition before magnesium treatment assures a large proportion of spheroidal graphite in the 0.01 to 0.02 per cent residual magnesium range.
2) This process offers magnesium alloy savings of 25 to 75 per cent for a ductile iron producer equipped with a direct-arc furnace.
3) Ductile irons so produced exhibit 80 to 100 per cent less drossing tendency than indirect arc furnace irons. The irons have good graphite structures and good physical properties.

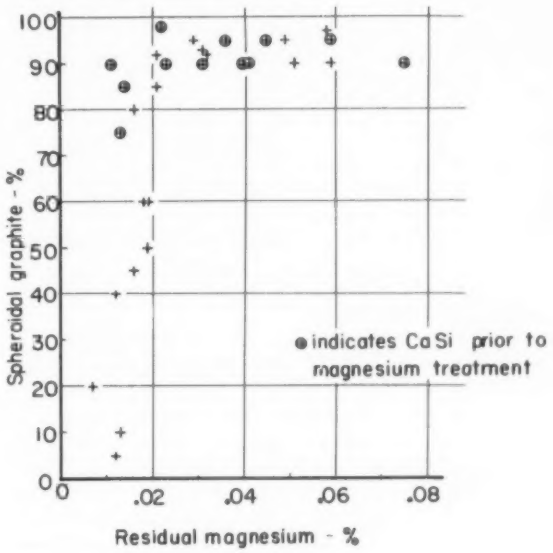


Fig. 7 — Residual magnesium vs. spheroidal graphite in 1-in. double keel block.

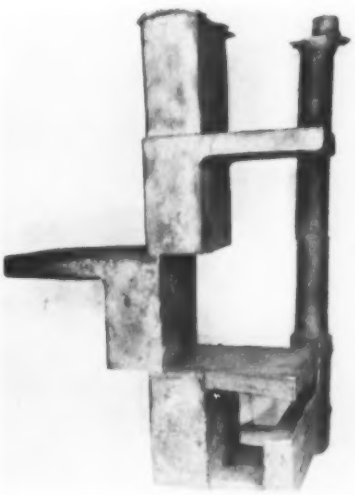

Fig. 8 — Test casting for dross measurement.

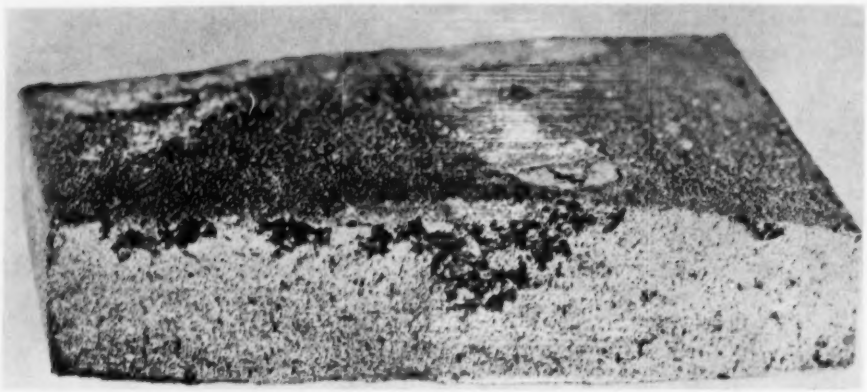

Fig. 9 — Fracture of dross test casting shelf showing moderate amount of dross. 1¼ ×.

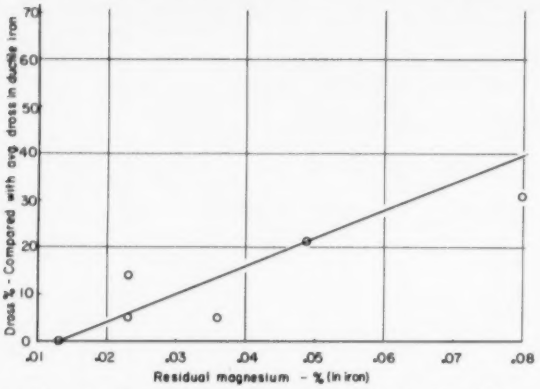


Fig. 10 — Dross in ductile iron melted in the basic direct-arc electric furnace.

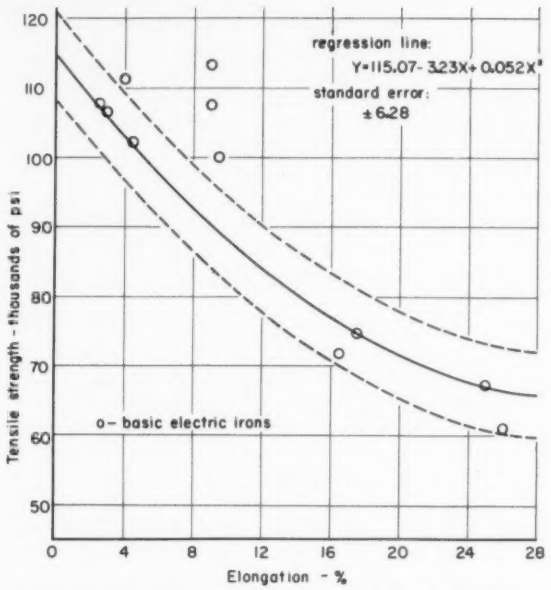


Fig. 11 — Tensile strength vs. elongation relationship of pearlitic-ferritic ductile irons.

4) Desulfurization of the melt to 0.005 per cent sulfur is accomplished under the basic slag by the time the cold charge has been brought to tapping temperature. Desulfurization of hot metal charges is also practical.
5) A 1 per cent to 3 per cent addition of calcium silicon and calcium carbide to the melt covered with a lime-fluorspar slag encourages introduction of up to 0.016 per cent calcium into the iron. This results in 15 per cent of the graphite in the base iron becoming spheroidal without further treatment. Improved physical properties accompany this change in structure.
6) Desulfurization with a dolomitic slag, followed by the late calcium silicon-calcium carbide slag addition, results in up to 0.028 per cent calcium in the iron and up to 50 per cent graphite spheroidization without further treatment.
7) Magnesium treatment of the desulfurized base iron can be accomplished entirely within the furnace. Ductile iron with 0.025 per cent residual magnesium is made by rabbling ½ per cent nickel-15 per cent magnesium alloy into this bath at 2750 F. Magnesium burnout from the treated iron in the furnace varies from about 0.001 per cent magnesium lost per min at 2710 F to about 0.002 per cent lost per min at 2780 F. Postinoculation of the treated iron can be done in the ladle during tapping.
8) Magnesium treatment of the desulfurized iron can be accomplished on tapout. Tapping onto ½ per cent nickel-15 per cent magnesium alloy at 2800 F results in an iron with about 0.025 per cent magnesium residual. Postinoculation is done on reladling.
9) A tensile strength-elongation relationship for good ductile irons was developed statistically, and was used to judge the irons produced in this investigation.

## ACKNOWLEDGMENT

Thanks and acknowledgment are extended to A. S. Kightlinger and his foundrymen with whose interest and skilled help these experimental heats were made; to R. D. Schelleng whose dross casting design and system of dross measurement were used; to Dr. J. T. Eash whose trials of the basic direct-arc electric furnace production of ductile iron indicated some possibilities of the method; and to The International Nickel Co., Inc., for permission to publish this paper.

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2. Chipman, J., "Chemical Behavior of Sulfur in Iron and Steelmaking," *Metals Progress*, pp. 97-107, Dec. 1952.

# A HYPEREUTECTIC ALUMINUM-SILICON ALLOY

By Rolf Kissling and Oldrich Tichy

## ABSTRACT

**Hypereutectic aluminum-silicon alloys have been improved through intensive research. Because of their low coefficient of thermal expansion, high hardness and excellent wear resistance, their potential was recognized early in their development.**

**One of the commercial hypereutectic aluminum-silicon alloys is analyzed, giving its structure and various properties, as well as foundry characteristics.**

**Mechanical properties, physical properties (including thermal conductivity, thermal expansion and dimensional stability) and some of the applications of this alloy are given.**

## DEVELOPMENT

Aluminum-silicon alloys gained little industrial importance until Pacz in 1921 patented the first process to modify the coarse eutectic silicon crystals, thereby improving the mechanical properties considerably. But the sodium modification of Pacz and his successors does not work with hypereutectic alloys, i.e., does not modify the coarse primary silicon crystals, the main disadvantage of these alloys. During the 1920's research therefore was concentrated mainly on eutectic and hypoeutectic alloys with continuing improvement in properties through alloying additions.

Nevertheless, based on their low coefficient of thermal expansion, their high hardness and excellent wear resistance, the potentials of the hypereutectic alloys were recognized and a number of patents appeared, each one with additions intended to refine the primary silicon and improve the properties. But additions such as copper, cobalt, antimony, chromium, nickel, titanium and vanadium merely strengthened the matrix, or acted as grain refiners at the most, without affecting the size and number of the primary silicon crystals. Machining still was extremely difficult, and interest in these alloys therefore faded while the foundry industry concentrated on the heat-treatable near-eutectic alloys.

During World War II, with its shortage of certain alloying elements, interest in the hypereutectic aluminum-silicon compositions again developed, particularly in Europe. Renewed research led to improved alloys, especially in the silicon range 18-35 per cent with a preferred content in the neighborhood of 21 per cent silicon. The researchers found limited use for pistons and small internal combustion engines, but machinability even with the newly developed carbide tools still left much to be desired.

Although the addition of phosphorus to hypereutectic aluminum-silicon alloys had been patented as far back as 1933,[1] it was not until the early 1950's that European workers[2,3,4,5,6,7,8] developed an effective method of refining the hypereutectic silicon with phosphorus to improve machinability, and thereby opened up a field of applications for these alloys.

## STRUCTURE

One hypereutectic alloy with a silicon content of about 21 per cent, is a commercial alloy (U.S. Patents 2357 449, 2357 450, 2357 451, 2357 452) of the following nominal composition:

| Mg % | Mn % | Si % | Cu % | Ni % |
|---|---|---|---|---|
| 0.7 | 0.5 | 21 | 1.8 | 0.4 |

The structure of this alloy shows primary silicon crystals surrounded by a complex, nonmodified eutectic. Magnesium and copper, through the formation of magnesium silicide and aluminum-copper-magnesium compounds, provide the desired heat treatability. Silicon, although soluble to the extent of about 1.6 per cent at the eutectic temperature and less than 0.1 per cent at room temperature, does not contribute noticeably to the heat treatment response. Copper in solid solution improves the dynamic properties, while manganese and nickel contribute to better strength at elevated temperatures.

The iron content is controlled by the use of special high-grade silicon with low iron developed in the authors' company. Since the liquidus temperature of a 21 per cent silicon alloy is appreciably higher than that of most commercial alloys, and the high latent heat of silicon also tends to slow down the rate of solidification, grain refiners are added to the alloy.

## REFINEMENT

The main difficulty with the early hypereutectic alloys consisted in their coarse primary silicon crystals which, due to their lower specific gravity tended to segregate and their large size ruined the machining tools. Various modifying compounds were known to influence the silicon, and in the early 1930's it was found in eutectic[9] and hypereutectic alloys[1] that small amounts of phosphorus break up and transform the lamellar silicon into a polyhedral form. The effect probably is due to the presence of nuclei

R. KISSLING is Met. and O. TICHY is Chief Met., Apex Smelting Co., Cleveland.

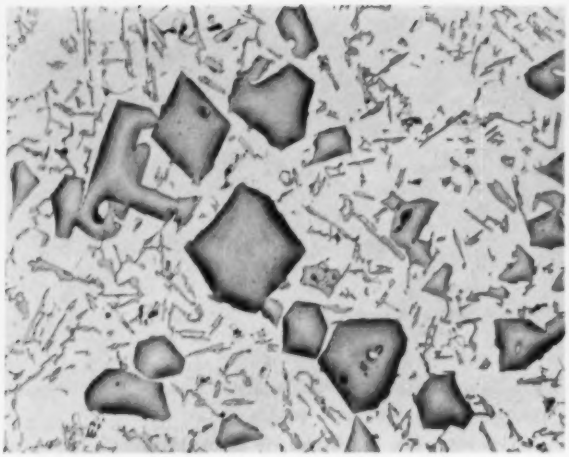

Fig. 1 — Microstructure of a hypereutectic alloy containing 21 per cent silicon and 0 per cent phosphorus. 100 ×.

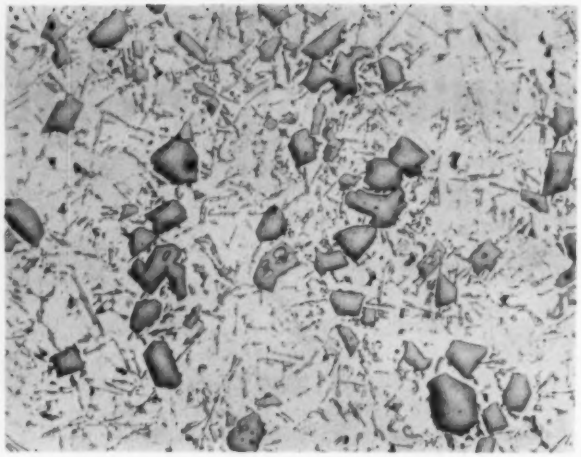

Fig. 2 — Microstructure of a hypereutectic alloy containing 21 per cent silicon and 0.01 per cent phosphorus. 100 ×.

and, like the sodium modification mechanism, is controversial.

The most important feature of the modified alloys is the marked increase in the dispersion of silicon. The phosphorus probably has a twofold effect:

1) It changes the crystal habit of the silicon.
2) It acts as a nucleating agent for the primary silicon.

But it seems that consistent results were difficult to obtain in commercial practice until it was found that the size[8] of the refining salts apparently plays an important role, and that sodium on the other hand tends to counteract the phosphorus effect.[5,6]

Care should be taken, therefore, that phosphorus-modified alloys are not contaminated with sodium in the foundry, for instance through sodium-containing fluxes of fluorides or carbonates. Unlike the sodium modification which disappears rapidly, the phosphorus refinement carries over into the remelts, possibly as much as three or four times, which is of great advantage to the foundryman. Chlorine can be used on the melts for cleansing without detrimental effects on the phosphorus modification; in fact chlorine is recommended for better results.[7,8]

Figure 1 shows a hypereutectic alloy containing 21 per cent silicon without phosphorus. The primary silicon is in the characteristic large form. An addition of 0.01 per cent phosphorus (Fig. 2) breaks up the coarse particles into smaller more rounded ones without affecting the eutectic structure.

## FOUNDRY CHARACTERISTICS

The fluidity of aluminum-silicon alloys increases with increasing silicon content. At 20 per cent silicon the curve starts to flatten out and seems to reach a maximum around 21 per cent silicon.[11] Since the cooling curve shows a primary arrest at approximately 1280 F which is unaffected by the phosphorus addition, the pouring temperature therefore must be higher than for most commercial alloys—1400-1450 F for sand and permanent molds, and 1300-1350 F for diecasting.

Hypereutectic alloys will have a slight tendency to hot-shortness of the same order as the commercial hypoeutectic alloys, hot-shortness being a function of the solidification interval. Feeding characteristics on the other hand are poor, due to the wide solidification interval and the corresponding mushy condition. Like any other alloy with a solidification interval and a primary crystallization, the hypereutectic alloys exhibit a certain amount of microshrinkage.

Therefore, feeding distances must be kept short and wide, but short risers should be used instead of the narrow and long risers used with eutectic aluminum-silicon alloys. Linear shrinkage is smaller than for most commercial aluminum alloys, of the order of 1.1 per cent.

## MECHANICAL PROPERTIES

The mechanical properties of the hypereutectic aluminum-silicon alloys depend strongly on the silicon content. Figure 3 shows the decrease in tensile strength with increasing silicon content. The nominal composition of the previously mentioned alloy given earlier is a compromise between low coefficient of expansion and high mechanical properties. For the intended special applications, the coefficient of thermal expansion and the wear resistance are of more importance than high mechanical properties. Table 1 gives the results obtained with separately cast test bars of a commercial heat of the composition:

| Mg % | Mn % | Si % | Cu % | Fe % | Ni % | P % |
|---|---|---|---|---|---|---|
| 0.77 | 0.58 | 20.30 | 1.66 | 0.65 | 0.37 | 0.01 (added) |

Due to the slow cooling in sand castings, the hardening constituents precipitate in relatively large particles with only a small amount retained in solid solution, and therefore the response of mechanical properties to an aging heat treatment is small. Permanent mold and die castings on the other hand show a definite increase. A solution heat treatment followed by a hot water quench and subsequent aging will give further improvement (Fig. 3).

Up to 400 F (Fig. 4) the influence of temperature is small, and at about 500 F the strength of the hyper-

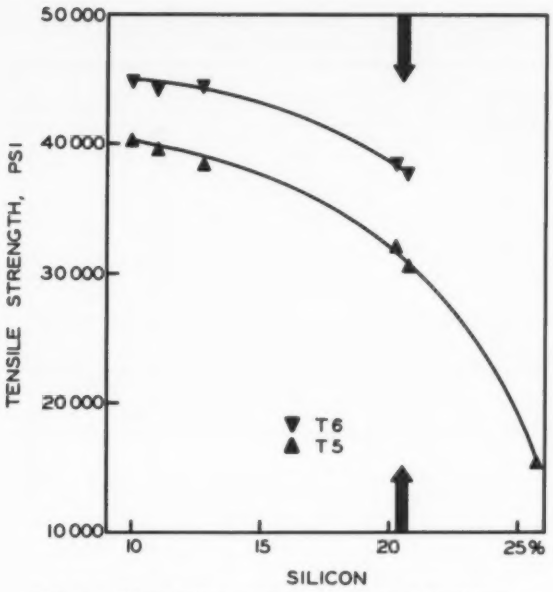


Fig. 3 — Silicon effect on tensile strength of aluminum-silicon alloys. Chill cast.

eutectic alloy compares favorably with that of forged A.S.T.M. CN 42 A (27,500 psi)[22] and chill cast A.S.T.M. SC 103A (23,000 psi)[23] alloy. The testing of mechanical properties after 1 hr at temperature seems to fairly measure the temperature effect. Longer times at temperature had almost no further effect on these properties, as illustrated in Fig. 5.

Short time elevated temperature properties are given in Table 2.

## PHYSICAL PROPERTIES

### Thermal Conductivity

The thermal conductivity of aluminum increases with increasing temperature. This is in contrast with ferrous metals where increasing temperature reduces the thermal conductivity. Alloying elements which form solid solutions with aluminum reduce its thermal conductivity. Silicon being only slightly soluble does not markedly affect the conductivity of the matrix. Since the thermal conductivity of this matrix in a solution heat treated condition is noticeably lower because of the larger amounts of dissolved elements, a heterogenous, i.e., completely precipitated structure is preferable from the viewpoint of thermal conductivity.

A chill cast specimen has a higher thermal conductivity than a sand cast one due to the finer and denser structure, and the modified alloy shows a slight advantage over the nonmodified. In the modified state the casting method, sand or chill cast, has little effect on thermal conductivity.[12] Typical results reported from various sources are shown in Table 3.

### Thermal Expansion

The hypereutectic aluminum-silicon alloys have the lowest coefficient of thermal expansion of known aluminum alloys, which makes them ideally suited for

TABLE 1 — MECHANICAL PROPERTIES AT ROOM TEMPERATURE* (AVE. OF 12 BARS TESTED)

| Item | Temper | Tensile Strength, psi | Brinell Hardness, HB |
|---|---|---|---|
| Sand Cast —F | As-Cast | 21,700 | 76 |
| —T5 | 400 F for 8 hr | 22,600 | 90 |
| Chill Cast —F | As-Cast | 25,100 | 87 |
| —T5 | 400 F for 8 hr | 32,000 | 102 |
| —T7 | 960 F for 6 hr — Hot Water Quench—400 F for 8 hr | 38,200 | 110 |
| Die Cast | As-Cast | 35,200 | 115 |

*Elongations 0-1 per cent.

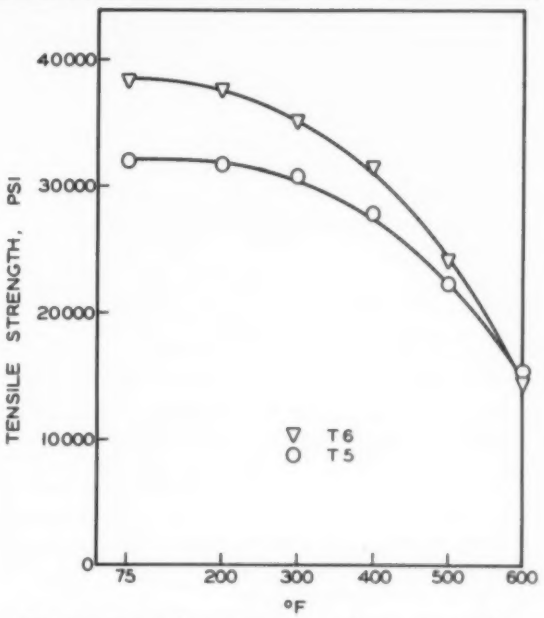


Fig. 4 — Elevated temperature effect on tensile strength. Mechanical properties tested after 1 hr at temperature. Chill cast.

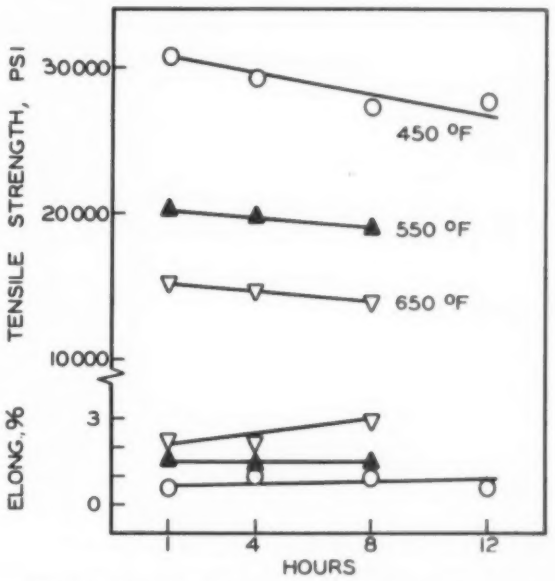


Fig. 5 — Length of time at elevated temperatures effect on elongation and tensile strength. Chill cast.

**TABLE 2 — SHORT TIME ELEVATED TEMPERATURE PROPERTIES**
**(Chill Cast: 1 hr at temperature. Ave. of six bars tested)**

| Temp., F | —T5 400 F/8 hr Tensile Strength, psi | Elong., % | —T7 960 F/6H—HWQ—400 F/8 hr Tensile Strength, psi | Elong., % |
|---|---|---|---|---|
| 75 | 32,000 | 0-1 | 38,200 | 0-1 |
| 200 | 31,700 | 0-1 | 37,800 | 0-1 |
| 300 | 30,900 | 1.0 | 35,200 | 0-1 |
| 400 | 27,800 | 1.0 | 31,600 | 0-1 |
| 500 | 22,300 | 1.4 | 24,200 | 1.0 |
| 600 | 15,300 | 1.9 | 14,500 | 2.6 |

**TABLE 4 — COEFFICIENT OF THERMAL EXPANSION: in./in./°F x $10^{-6}$**

| Composition, % | | | | | Temperature, F | | | |
|---|---|---|---|---|---|---|---|---|
| Cu | Mg | Ni | Mn | Si | 68-212 | 68-392 | 68-572 | 68-752 |
| 1.6 | 0.5 | 0.4 | 0.5 | 8.1 | 11.9 | 12.3 | 12.9 | 13.2 |
| | | | | 9.8 | 11.6 | 12.2 | 12.7 | 13.0 |
| | | | | 10.8 | 11.4 | 12.0 | 12.5 | 12.9 |
| | | | | 12.3 | 11.2 | 11.6 | 12.1 | 12.4 |
| | | | | 16.2 | 10.3 | 11.0 | 11.6 | 11.9 |
| | | | | 20.1 | 9.9 | 10.4 | 10.8 | 10.9 |
| | | | | 21.1 | 9.8 | 10.2 | 10.7 | 11.0 |
| | | | | 25.6 | 9.1 | 9.5 | 9.8 | 10.0 |
| | | | | 26.2 | 9.1 | 9.4 | 9.7 | 9.9 |

**TABLE 3 — THERMAL CONDUCTIVITIES: cal/sq cm/sec/cm/°C**

| Composition, % | | | | | 75 F (24 C) | 200 F (93 C) | 400 F (204 C) | 600 F (318 C) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| Si | Mg | Cu | Ni | | | | | | |
| 7 | 0.3 | | | sand—T6 | 0.36 | | | | 14 |
| | | | | chill—T6 | 0.38 | | | | 14 |
| 8 | 0.7 | 1.5 | | chill—F | 0.25 | | | | 18 |
| | | | | —T5 | 0.27 | | | | 18 |
| 12 | 0.8 | 1.0 | 2.5 | chill—T55 | 0.28 | | | | 14 |
| 20 | 1.0 | 2.0 | | sand—T5 | 0.20 | | | | 12 |
| | | | | chill—T5 | 0.22 | | | | |
| 12 | 0.5 | 1.2 | | chill—T4 | | | 0.337 | 0.350 | 13 |
| | | | | —T7 | | | 0.378 | 0.379 | 13 |
| 12 | 0.3 | | | chill—T4 | | | 0.354 | 0.365 | 13 |
| Pure aluminum | | | | | | | 0.540 | 0.538 | 14 |
| Automotive cast iron | | | | | 0.112 | 0.110 | 0.107 | 0.105 | 15 |

such applications as pistons, cylinders, brake drums, etc. Silicon has the strongest effect in reducing the thermal expansion of the common alloying elements in the commercial ranges. The coefficients of thermal expansion for the range 68-392 F of various aluminum-silicon alloys are tabulated in Table 4, and plotted as a function of the silicon content in Fig. 6. The linear relationship can be seen.

Included also are the values for automotive cast iron (7.1 x $10^{-6}$ in./in./°F)[15], and the formerly widely used A.S.T.M. CN 42 A alloy (12.6 x $10^{-6}$ in./in./°F).[16] The coefficient of thermal expansion as a function of temperature in the ranges from 68-750 F of aluminum-silicon alloys containing 12 per cent, 21 per cent and 25 per cent silicon, are shown in Fig. 7. A similar curve for cast iron[15] is included for comparison.

### Dimensional Stability

Aluminum alloys, like most metallic alloys, have slightly different densities depending on the temper. The corresponding dimensional variations are commonly called permanent growth, or simply growth. In aluminum alloys, growth is generally considered to be the result of a precipitation of alloying constituents from a supersaturated solution such as pro-

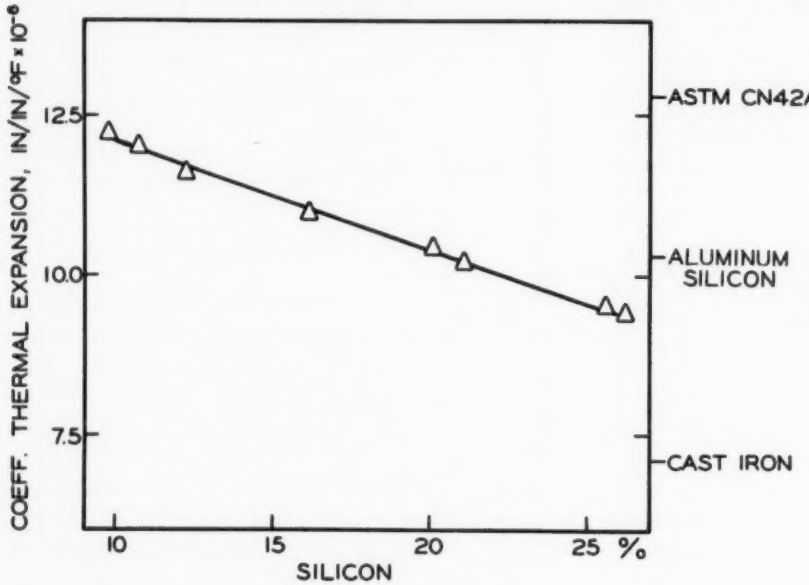


Fig. 6 — Silicon effect on the coefficients of thermal expansion of aluminum-silicon alloys in the range of 68 — 392 F. Chill cast.

TABLE 5 — INFLUENCE OF AGING TEMPERATURE ON DIMENSIONAL CHANGES, CHILL CAST

| Time, hr | 400 F in./in. × 10⁻³ | 450 F in./in. × 10⁻³ |
|---|---|---|
| 2 | 0.137 | 0.211 |
| 4 | 0.146 | 0.314 |
| 6 | 0.187 | 0.309 |
| 8 | 0.217 | 0.314 |
| 10 | 0.244 | 0.330 |
| 12 | 0.261 | 0.359 |
| 14 | 0.277 | 0.349 |
| 16 | 0.291 | 0.361 |
| 21 | 0.309 | 0.364 |
| 30 | 0.350 | 0.377 |
| 36 | 0.366 | 0.397 |
| 40 | 0.361 | 0.396 |
| 44 | 0.367 | 0.384 |
| 54 | 0.369 | 0.369 |
| 72 | 0.381 | 0.384 |

TABLE 6 — TYPICAL VALUES OF TENSILE STRENGTH AND CORRESPONDING REMOVAL OF GROWTH, CHILL CAST

| | Tensile Strength, psi | Growth Removed, % |
|---|---|---|
| As-Cast | 26,000 | |
| 960 F/6 hr — Hot Water Quench — | | |
| 300 F for 3 hr | 35,000 | |
| 355 F for 12 hr | 37,000 | |
| 400 F for 8 hr | 38,000 | |
| 355 F for 12 hr | 33,000 | |
| 400 F for 8 hr | 30,000 | 55 |
| 450 F for 8 hr | 28,000 | 85 |

duced by a solution heat treatment and subsequent quenching. It should vary, therefore, with the temperature of reheating in the same manner as the solid solubility of the alloying elements concerned.

The time to maximum growth is a logarithmic function of temperature, but does not coincide with that for maximum hardness. At slightly elevated temperatures growth takes place so slowly as to be of no practical importance, while the upper limit of the reheating temperature is fixed by the necessity of getting a high combination of mechanical properties. Since growth take place later in time than hardening, maximum mechanical properties and complete freedom of growth cannot be obtained simultaneously. The heat treatment, therefore, is necessarily a compromise between an aging treatment and a degrowthing treatment.

However, it must be noted, that dimensional changes are not necessarily due to growth. Machining, for example, can release internal stresses with an increase in dimensions. An internal or service stress of 15,000 psi for instance, produces a dimensional increase equivalent to the maximum growth of most commercial alloys. The same holds true for a thermal expansion due to a temperature rise of only 100 F.[17]

The hypereutectic aluminum-silicon alloy mentioned previously under "Mechanical Properties" exhibits a freedom from growth unique among the usual piston alloys and other aluminum alloys of the copper-silicon type. Typical values are shown in Table 5.

The permanent growth of this alloy is plotted against time at temperature (logarithmic scale) in Fig. 8. The effect of several heat treatments on the tensile strength and growth is illustrated in Table 6. It can be seen that with a simple aging treatment the peak values probably should be obtained with 12 hr at 355 F in commercial practice, while the commonly used heat treatment of 8 hr at 400 F or 450 F leads to a slight over-aging.

However, considerably more stress relief and degrowthing takes place at these higher temperatures, which in many cases is of more importance than a slight loss in properties.

## APPLICATIONS

The combination of low coefficient of thermal expansion and high wear resistance makes the hypereutectic aluminum-silicon alloys particularly suitable for applications such as pistons, brakes,[19] internal combustion engines, etc. Their use in small gas en-

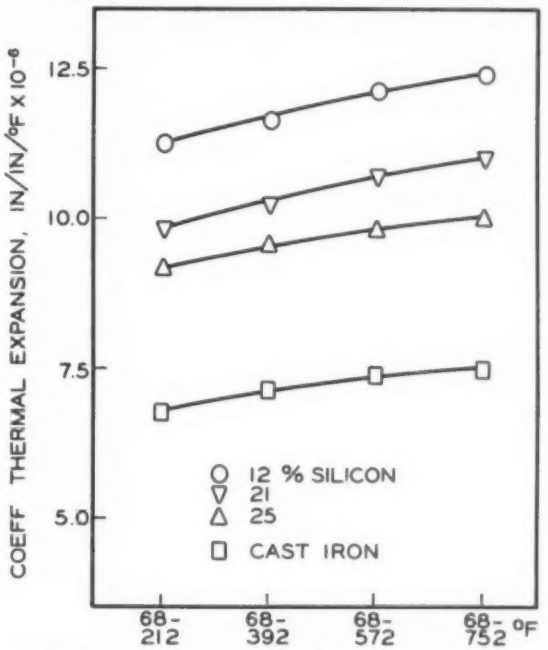


Fig. 7 — Coefficients of thermal expansion as a function of temperature in ranges of 68 — 750 F of alumninum-silicon alloys containing 12 per cent, 21 per cent and 25 per cent silicon. Chill cast.

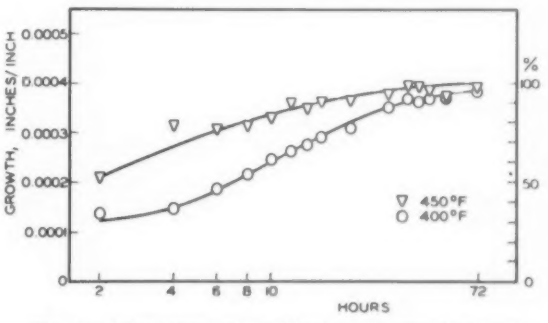


Fig. 8—Aging temperature effect on permanent growth of tested alloy plotted on logarithmic scale.

gines was started some time ago, and the results point to excellent possibilities for automotive engines where early research and development work led to sand, semi-permanent mold and diecast engine blocks with wet or dry aluminum and cast-iron liners.[20]

The perfecting of the hypereutectic aluminum-silicon alloys makes an all-aluminum engine look attractive. The entire block can be cast in the previously mentioned alloy thereby eliminating the need for liners, or an aluminum block can be fitted with liners of this alloy. These liners will be either cast or extruded and forged. The use of the same material for the pistons is a natural consequence, since the necessary clearances can be greatly reduced.

The early difficulties with valve seats (experienced for example in aluminum heads for aircraft engines) have successfully been overcome in automotive blocks by the use of pressed-in seat rings made of special cast iron.[21] Work is under way between foundries and automotive manufacturers, and the mutual efforts will undoubtedly lead to a wide use of aluminum and its alloys in these products.

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# PROPER GATING THROUGH USE OF COBALT 60

By A. J. Karam


## ABSTRACT

Nondestructive testing by use of cobalt-60 radiography has helped the author's company improve the quality of their castings. The company makes a threefold use of this type of inspection:

1) To check new casting design before production begins.
2) To design gating layouts to produce highest quality castings at lowest cost.
3) To establish inspection standards.

Examples of how cobalt-60 (gamma) radiological inspection has helped various castings produced in a proprietary pearlitic malleable iron are given.


## INTRODUCTION

During recent years, the foundry industry has witnessed advancements which require improved casting techniques and better inspection media. One inspection medium, Cobalt-60 radiography, enables the author's company to provide customers with quality castings at reduced cost, and in a minimum of time.

A proprietary pearlitic malleable iron makes castings suitable for many applications which were formerly forgings, stampings and fabrications. When castings replace other materials in applications where soundness is a major consideration for satisfactory performance, it is especially important to utilize inspection methods which assure castings free from internal defects of any kind.

The traditional method of inspecting castings for internal defects in the foundry was cutting, breaking (Fig. 1) and etching. This procedure not only destroyed the casting, but was time consuming and costly, without a guarantee that the presence of a defect would always be located.

Shrinkage voids usually constitute the largest portion of sub-surface defects in castings. Shrinkage in a casting is caused by the lack of sufficient liquid feed metal to make up for the contraction, which occurs during solidification from liquid to a solid form.

## FEEDER SIZE EFFECT

The size of the reservoir or feeder containing the liquid feed metal affects the internal soundness of a casting. In Fig. 2 are three sectioned castings made with varying heights of feeders. At left is a sound, shrink-free casting. The center casting has an extensive area of light internal shrinkage or porosity as indicated by the dark etch stained area on the casting. Casting on the right has a severe internal shrink void at the top with a lighter area of porosity below it.

Figure 3 shows the same group of castings as they appear on a radiograph. On the left is a sound casting, while the middle casting is an example of slight internal shrinkage as indicated by the dark spots and the right-hand casting shows severe internal shrinkage.

The author's company's use of Cobalt 60 is three fold:

1) To check new casting designs before they are released for production.
2) To design gating layouts which will produce the best quality castings at the lowest possible cost.
3) To establish standards for inspection by other methods.

## COBALT 60 INSTALLATION

The installation contains a 30-curie Cobalt-60 unit, housed in a special windowless building having poured concrete walls three feet thick (Fig. 4). The cobalt-60 source, which is approximately the size of a pencil eraser, has the equivalent penetrating power of a 2 million volt x-ray machine. The gamma radiation from cobalt 60 reacts on film similar to x-rays.

Gamma radiation must be respected at all times, and properly controlled by trained personnel. It cannot be turned on and off like an x-ray unit. Instead, it must be retracted into a lead housing which is designed to reduce the radiation to a safe level.

### Precautions

The control panel is located outside the exposure room behind an electrically interlocked door, and in conjunction with signal warning lights. A gamma survey meter (Fig. 5) is used to monitor the room after each exposure as a safety measure.

Film badges and pocket dosimeters (Fig. 6) are worn by personnel to detect the amount of radiation

Fig. 1 — Traditional method of inspecting castings for internal defects was by cutting (left), breaking (right) and etching.

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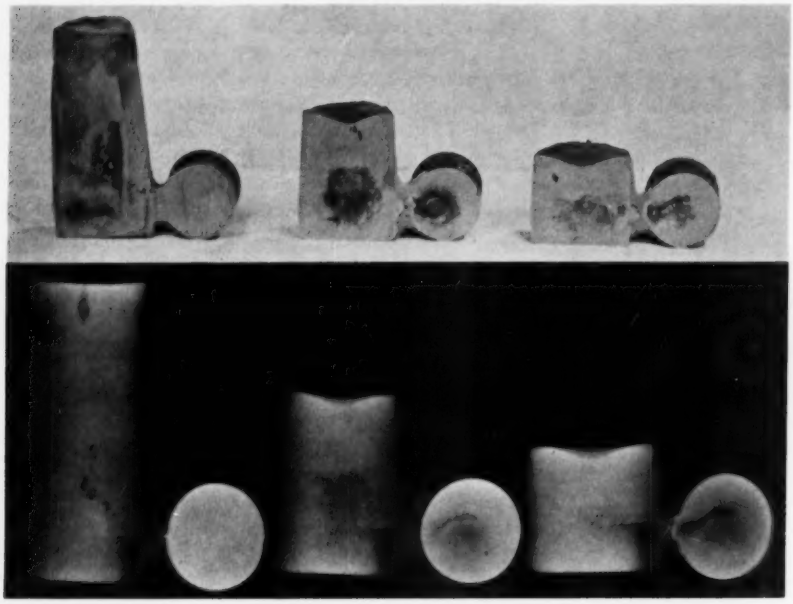

Figs. 2 and 3 — Three sectioned castings made with varying heights of feeders (top), and as they appear on a radiograph (bottom). At left is a sound, shrink-free casting. The center casting has an extensive area of light internal shrinkage or porosity (dark areas). The casting on the right has a severe internal shrink void at the top with a lighter area of porosity below it.

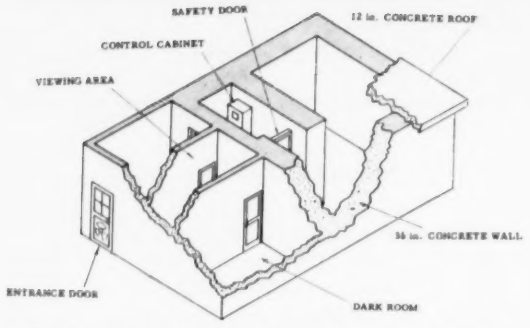


Fig. 4 — Special housing for cobalt-60 unit, showing main features of installation.

exposure. On the right of Fig. 6 is shown a film badge which creates a permanent record of radiation dose (milliroentgens) received during a period of time, usually one week (A milliroentgen is a unit of radiation. It is a measure of the film darkening effect or possible damage to animal tissue). On the left of Fig. 6 is a pocket dosimeter which records accumulated dose in mr (milliroentgens) of radiation. This instrument can be read at any time without waiting for a film badge report.

Fig. 5 — A gamma survey meter is used to monitor the room after each exposure as a safety measure.

The cobalt source is housed in a small stainless steel capsule in the center of a 1000 lb lead container (Fig. 7). It is moved to the exposure position by remote control. Exposure time is decided by the strength and age of the cobalt source, type of film used, casting section size and distance from source to film. All developed radiographs are read on a high intensity viewer by personnel trained to interpret the film accurately.

## DESIGN CHANGES

Figure 8 shows how radiography was used in work on the elimination of one gate and feeder on a differential carrier. The first samples were made using three gates and feeders, two on the flanges and one on the tube as indicated. This tube gate is not a part of the mold, but is formed with a separate gate core.

Figure 9 shows a cutaway view of the position of the gate core in relationship to the casting. This adds cost and extra operations to the making of the casting, which makes it desirable to eliminate the tube gate. In Fig. 10 is the radiograph of the casting made in this manner, showing slight shrinkage (circled area) in the tube gate area. This indicated that this feeder was not providing adequate feed. Many variations with two flange gates were tried until satisfactory castings were made.

This was accomplished by a redesign of the part (Fig. 11), which added five ounces of metal to a thin section near one gate for effective feeding and the use of one chill in the tube area. This chill enabled the author's company to equalize the cooling rate of this heavy, isolated tube section without the use of an additional feeder. These changes resulted in a sound quality casting of improved design, as shown in Fig. 12.

Cobalt-60 radiography is also being used to lower

costs by reducing the amount of waste metal in feeders and runners to produce a given casting. Uniform sections and good design enable the foundryman to get the maximum number of good castings per mold with minimum amount of gating.

Quality castings at lower cost is the ultimate goal of the foundry engineer, and is accomplished only by a series of methodical steps on each job. Development of a better gating layout is done step by step through a series of changes, and radiography shows the results brought about by each change.

A typical example of improving foundry practice through the use of cobalt-60 is a steering gear housing casting which was gated in the same manner as many of the housings of this type. Figure 13 a radiograph of this casting with its attached feeders. Note that the feeders marked 1, 2, 3 and 4 showed little internal shrinkage. This is a sign of excess feed metal (Note slag catcher marks on radiograph).

It was decided to reduce the height of feeders 1, 2 and 3 by 1½ in., and through a design change to eliminate feeder 4. A small amount of metal was added to the wall of the tube section to permit feeders 1, 2 and 3 to feed this section through progressive solidification.

These changes were too drastic, since shrinkage voids appeared in the vicinity of feeders 2 and 3, as marked (circled areas) in Fig. 14. Note that no shrinkage voids appeared in the vicinity of feeder 1, indicating sufficient feed metal at this point.

The volume of metal in feeders 2 and 3 was increased by raising the feeders ½-in. in height (Fig. 15). This additional metal was sufficient to eliminate the shrinkage voids, and resulted in the sound casting. This is an excellent example of how a small engineering change supported by radiography eliminated the need for a feeder.

Figure 16 shows a universal joint yoke that is made in the proprietary pearlitic malleable iron, with a single gate and feeder on the tube of the casting. An engineering change request by the customer reduced the wall thickness along the entire tube $\frac{1}{16}$-in. After this pattern change was completed, sample castings

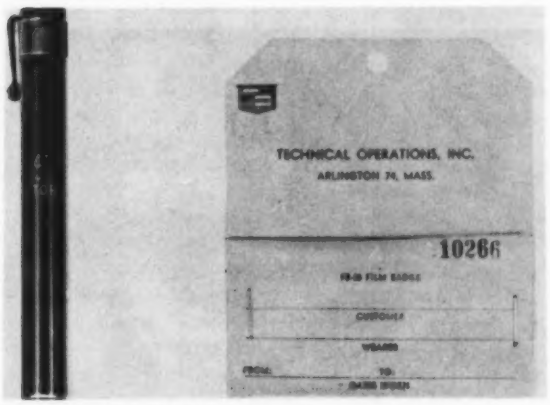


Fig. 6 — Film badges and pocket dosimeters are worn by personnel to detect the amount of radiation exposure. The pocket dosimeter (left) records accumulated dose of radiation in milliroentgens. The film badge (right) creates a permanent record of radiation dose in milliroentgens received during a period of time (usually a week).

Fig. 7 — The cobalt source is housed in a small stainless steel capsule in the center of a 1000 lb lead container (left). It is moved to the exposure position by remote control.

(Fig. 17) were checked radiographically, and shrinkage voids were found in the yoke arm away from the gate (circled areas). The feeder was radiographed, and found to have sufficient feed metal. This indicated that the decreased section thickness of the tube was causing the shrinkage voids. The section thickness of the casting in this area was increased to permit adequate feeding (Fig. 18). This was done to the inside diameter of the tube from the gate area to the yoke arm, and sound castings were produced using this gating.

Figure 19 is a small gasoline engine crankshaft made in the pearlitic malleable iron with two gates and

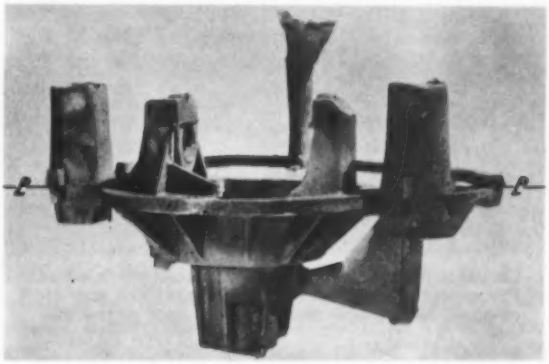

Fig. 8 — Radiography was used in work on the elimination of one gate from this differential carrier.

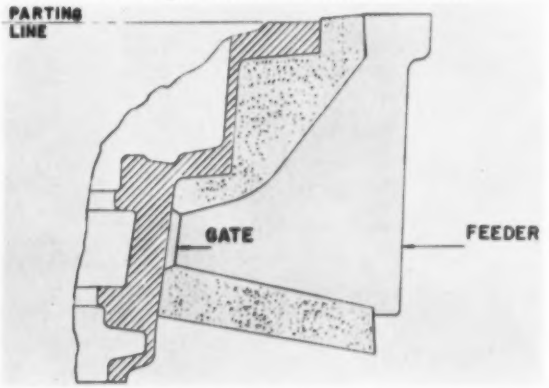


Fig. 9 — Cutaway view of differential carrier shown in Fig. 8, indicating position of gate core in relationship to the casting.

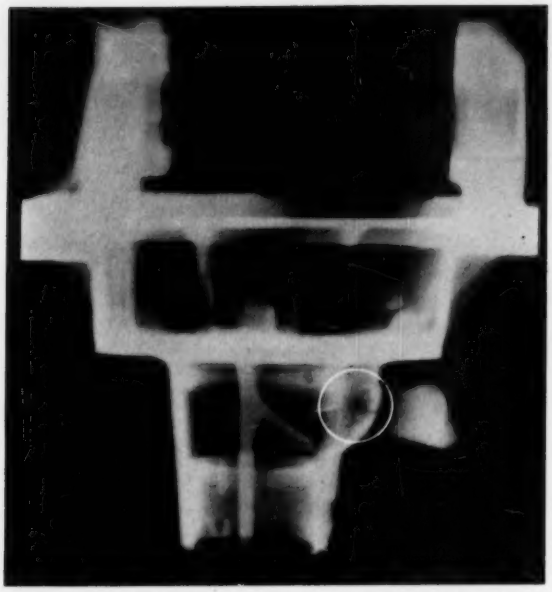

Fig. 10 — Radiograph of casting (Fig. 8) with tube gate, showing (circled area) slight shrinkage in area of tube gate. This indicated that the feeder was not providing adequate feed to the casting.

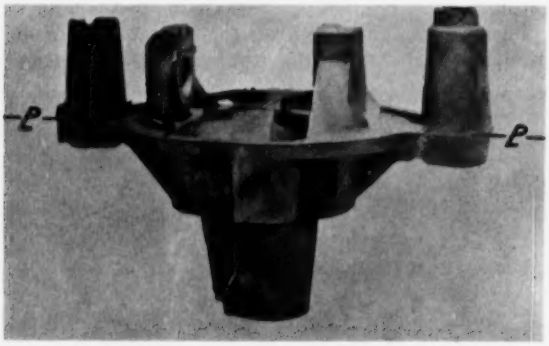


Fig. 11 — Redesign of casting in Fig. 8 which added five ounces of metal to thin section near one gate for effective feeding and the use of one chill in the tube area.

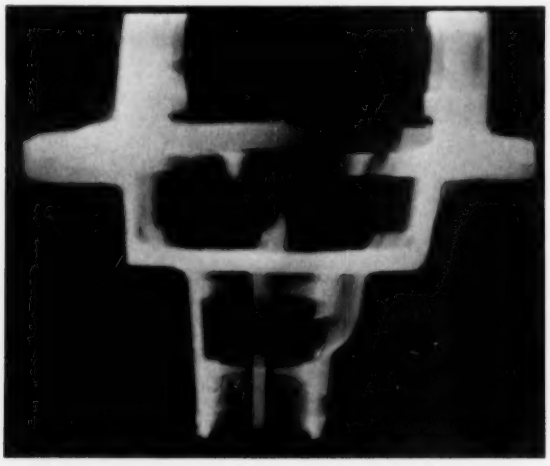

Fig. 12 — Radiograph of redesigned casting in Fig. 11, showing sound quality.

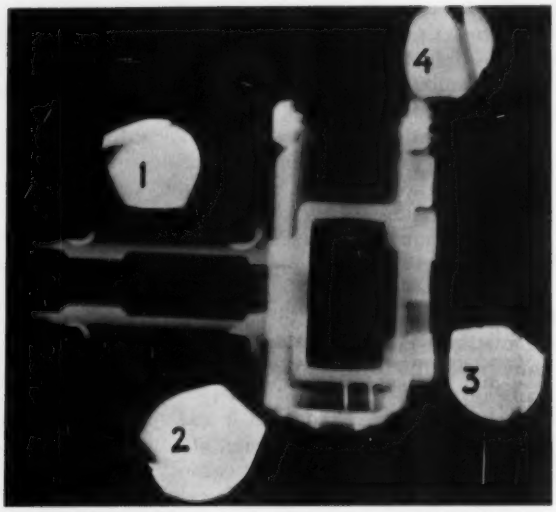


Fig. 13 — Radiograph of steering gear housing casting with its attached feeders. Little internal shrinkage is shown in feeders 1, 2, 3 and 4. This is a sign of excess feed metal. Note slag catcher marks on radiograph.

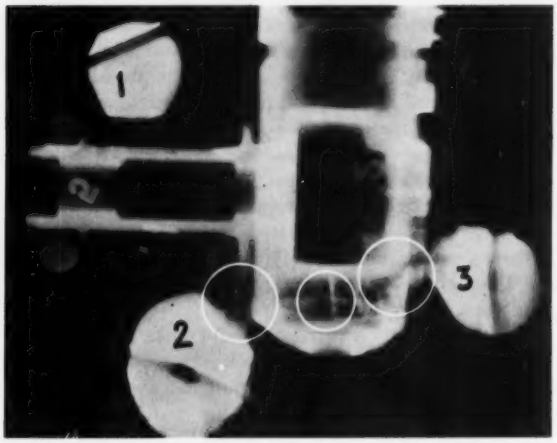


Fig. 14 — Elimination of feeder 4 proved too drastic, as shown in radiograph, since shrinkage voids appeared in the vicinity of feeders 2 and 3 (circled areas).

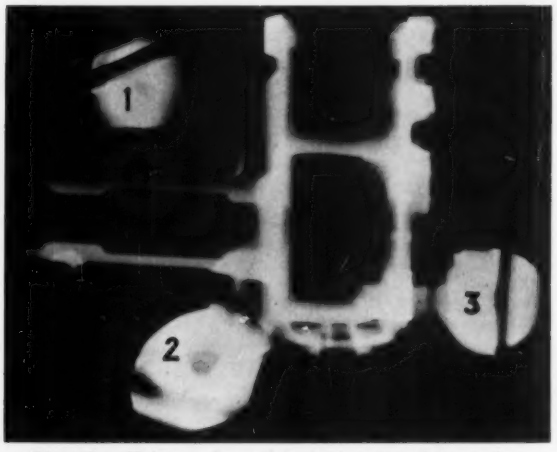


Fig. 15 — Volume of metal in feeders 2 and 3 was increased by raising height ½-in. The additional metal was sufficient to eliminate shrinkage voids, and resulted in the sound casting.

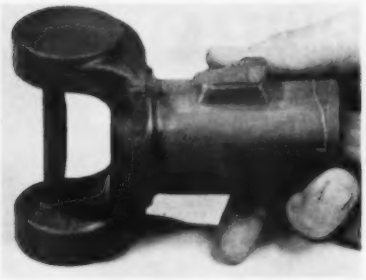

Fig. 16—Universal joint yoke with single gate and feeder on the tube of casting.

feeders. This gating was considered necessary to produce a sound casting because of the geometry of the part (Fig. 20). Also, a small tie bar was required between the two counterweights to prevent distortion during annealing. Because the gates were on a contoured surface removal by grinding was a costly time-consuming operation.

These gates could not be ground to an exact contour by hand, which presented the customer with problems in his machine shop by causing an intermittent cut during the turning operation on the shaft. Also, the gates made the shafts difficult to straighten by pressing because of irregular die contact in processing at the plant. An engineering change (Fig. 21) was made to determine the possibility of feeding the castings by combining the two gates in the form of an enlarged tie bar, which could be removed with a milling operation.

Experimental castings made in this manner were satisfactory (Fig. 22), and a pattern change was made to incorporate this into the production equipment. These castings were processed by the customer without the previous machining difficulties, and the author's company was able to supply straighter crankshafts because the elimination of the gates on the shaft diameters gave better contact in the straightening fixtures. These changes resulted in a cost reduction of 2.3 per cent.

The proprietary pearlitic malleable iron is being used as a replacement material in many instances where forgings had been used previously. One of these is an automotive connecting rod (Fig. 23) which was made experimentally using four gates and feeders to produce a sound casting. However, because of gate removal problems and costs, it was necessary to improve the gating. Through the use of cobalt 60, these castings could be made with two gates and feeders (Fig. 24).

The design of the casting in the bearing cap area was altered by increasing the section thickness between the balancing lug and the bolt bosses. This made it possible to obtain sufficient feed for the bolt boss areas with one feeder instead of the three previously used.

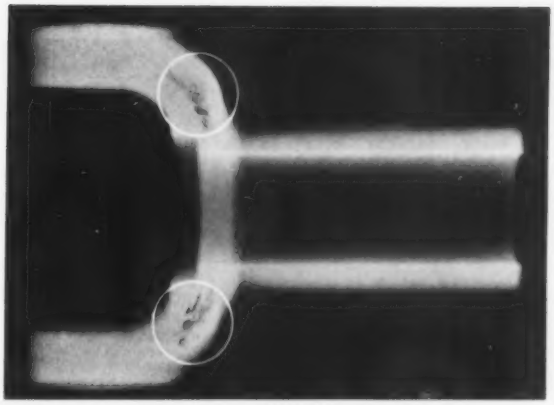

Fig. 17 — After a change in design which reduced wall thickness $\frac{1}{16}$-in., sample casting showed shrinkage voids on radiograph in yoke arm away from gate (circled areas).

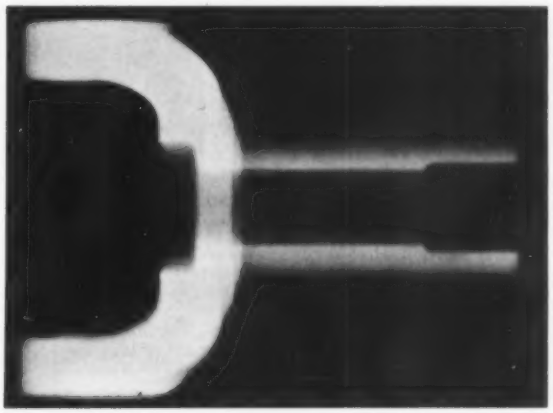

Fig. 18 — The section thickness of the casting (Figs. 16, 17) was increased in this area to permit adequate feeding. This was done to the inside diameter of the tube from the gate area to the yoke arm, and sound castings were produced.

This small addition to metal to the casting gave a radiographically sound part (Fig. 25). These shell molded connecting rods have stood up under many tough fatigue tests, and are being tested in automobiles today.

Cobalt 60 is also an aid in setting up and controlling other forms of casting inspection. It is a rapid method of determining the seriousness of a defect, and helps set up sound inspection standards without destroying the part. For example, sonic frequencies are verified for a set control point by radiographing the castings and establishing standards for the process.

Another example of how this radiography is used at the author's company is shown in Fig. 26, which shows a group of cast crankshafts being set up in one of the

Fig. 19 — Small gasoline engine crankshaft made with two gates and feeders of pearlitic malleable iron.

Fig. 20 — A small tie bar was required between the two counterweights to prevent distortion during annealing on crankshaft shown in Fig. 19.

Fig. 21 — An engineering change in casting (Fig. 19) was made in order to determine the possibility of feeding the casting by combining the two gates in the form of an enlarged tie bar.

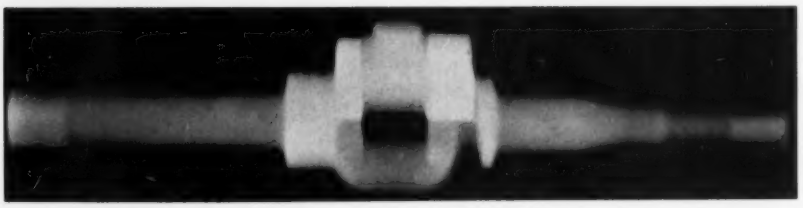

Fig. 22 — Experimental casting made with enlarged tie bar (Fig. 21) was satisfactory.

facilities. This is only one of the many products which are inspected by the means of cobalt-60 radiography.

In summarizing, the major benefits of cobalt 60 have been found to be:

1) The assurance of internal soundness provides the correct safety factor in gating.
2) The time element in development of a part is greatly reduced.
3) Radiography enables sound casting techniques with a minimum of pilot casting trials.
4) Also, the process broadens sales opportunities by aiding in enlarging the scope of casting application in industry.

The potential of this process is virtually unlimited. Cobalt-60 radiography substantially aids in the production of castings of the highest quality at the lowest possible costs for the author's company's customers.

Fig. 23—An automotive connecting rod made experimentally using four gates and feeders to produce a sound casting.

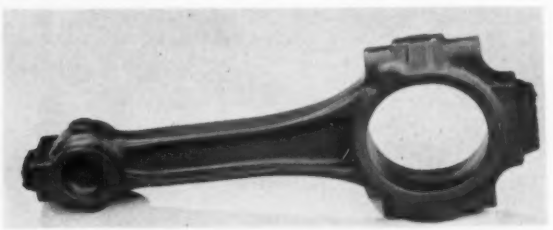

Fig. 24 — Through use of cobalt 60, these castings (Fig. 23) could be made with two gates and feeders, through altering the design in the bearing cap area.

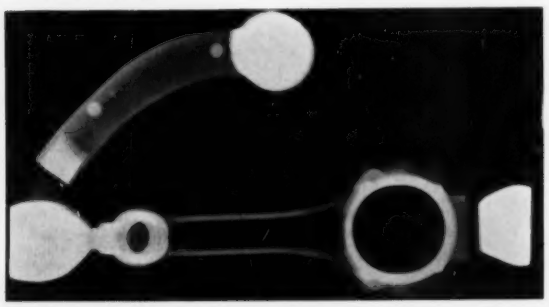

Fig. 25 — The additional metal added by increasing section thickness produced a radiographically sound part.

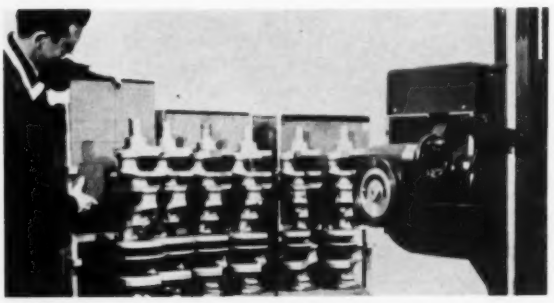

Fig. 26 — Group of crankshafts being set up for radiography.

# STEEL CASTINGS FOR THE AIRCRAFT INDUSTRY

## *quality requirements*

By Y. J. Elizondo


## ABSTRACT

The need for quality steel castings in the aircraft industry is readily understood when the aircraft and missile design requirements are reviewed. The experiences of one aircraft company over the past three years are summarized to illustrate various reasons for success or failure of several steel casting designs.

Most of the problems and troubles which exist today are not due to technical reasons, but are the direct result of misunderstandings existing between the two industries. Recommendations are made for eliminating or at least reducing this source of problems.

In order to achieve optimum utllization of steel castings in the aircraft industry, which is required to keep up with the state of the art, several improvements must be made in the foundry practices. In addition, technological advances will also be required to keep up with the modern design requirements. Recommendations for achieving these goals are presented.


## INTRODUCTION

For the past several years engineers at the author's company have tried to incorporate precision steel castings in both aircraft and missile designs. This effort, although initiated for economic reasons on the individual designs, was also supported by the knowledge that steel castings would become essential for the support of future designs. This trend is readily evident from data in Fig. 1, which presents the number of steel castings used by the company on two general types of designs. Although the actual number of castings will be a function of the design, the trends indicated are representative. It is worth noting that the discontinuity in the upper curve coincides with the above mentioned effort.

It should also be noted that Fig. 1 represents only a portion of the total number of potential steel casting applications. Many potential applications reverted to other forms of fabrication when the steel casting supplier was unable to produce a part with the required performance. It will be the purpose of the following discussion to clarify some of the requirements which prevented the utilization of all the casting designs.

In order to proceed without any confusion a definition of structural aircraft castings is needed. If an aircraft or missile were to have the skin, hydraulic system, electrical system, fuel system, electronic equipment, instruments, and the like removed there remains a skeleton which can be referred to as the primary structure. The subject castings would be those which form a part of this basic skeleton. They are by no means all the castings used in an aircraft or missile, but they do represent those which are causing the greatest amount of trouble to both the foundries and the aircraft designer. In addition they represent the largest potential market to the casting vendor.

Figure 2 illustrates several typical examples of this type of casting. For example, the 95 structural castings used in one design represent approximately 176 lb or only about 2 per cent of the airframe weight. In this same design there were four additional castings proposed which were not used due to foundry problems, design details and schedule difficulties which would approximately double the weight of the castings used on this design. In retrospect, several

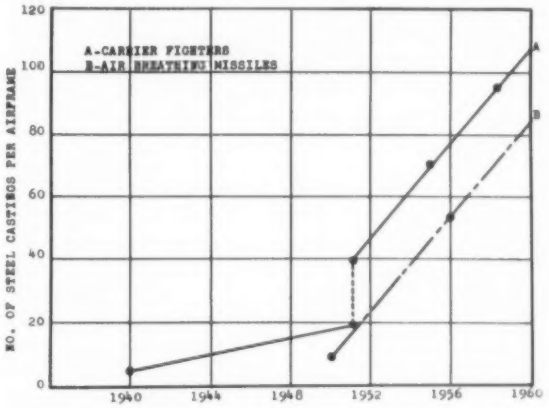


Fig. 1 — Steel castings used on aircraft designs at the author's company.

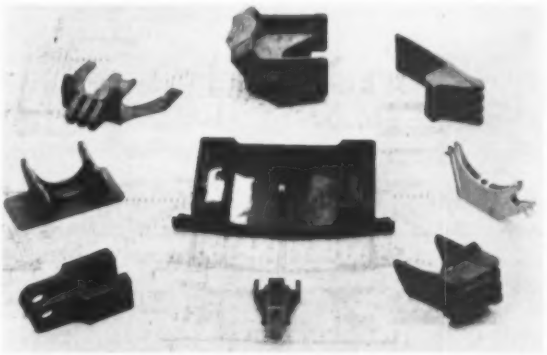

Fig. 2 — Typical structural aircraft castings.

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other casting applications have been discovered, and at the present time three of these casting applications are being cast as part of a steel casting program sponsored by the Air Material Command, and on which the author's company is the prime contractor.

These three castings would increase the weight of the steel castings used on this design by approximately 140 lb. It is easy to see that the trend in Fig. 1 could easily be doubled or even tripled if a better understanding existed between the foundries and the aircraft designers.

## AIRCRAFT AND MISSILE DESIGN REQUIREMENTS

To better understand the requirements for the steel casting, a brief knowledge of the design requirements being imposed on the aircraft designer is necessary. With the advent of supersonic speeds the problem of aerodynamic heating becomes a significant factor. Almost any article today will present a picture of the temperatures that can be expected at various altitudes and speeds. These temperatures for existing aircraft are already of the order of 300 F and 600 F. With the advent of intercontinental missiles and space and satellite programs the temperature encountered will become even higher.

Designs already exist where temperatures in the order of 1000 F to 2000 F will be attained, and there are other experimental designs where even higher temperatures are expected. The first visible result of this temperature problem was the gradual increase in the use of ferrous alloys in aircraft and missile designs.

This change to ferrous alloys magnified an already critical design requirement—weight. While weight has always been a critical factor in aircraft design, more so than in other applications, the use of ferrous alloys magnifies this problem. In general, the actual weight increase of a particular component is only a small portion of the total weight penalty for the aircraft or missile. For example, considering the wing of an airplane or missile as a simple cantilever beam any increase in the weight of a component near the wing tip requires an increase in load carrying ability of practically all structure inboard of the component.

This results in a weight increase for many components other than the original culprit. In turn, if this weight increase is significant it may cause a drop

| SHAPE | SIZE INCHES | AREA SQ. INCHES | SECTION MODULUS $I_{xx}/C$, $IN^3$ | STRUCTURAL INDEX $Z/A$ |
|---|---|---|---|---|
| | 1 | 0.785 | .098 | .125 |
| | 1 x 1 | 1.000 | .167 | .167 |
| | 2 1/2 x 1 1/2 x 1/4 | 1.000 | .266 | .284 |
| | 2 1/2 x 1/8 | 0.938 | .406 | .476 |
| | 3 x 1 3/4 x 1/8 | 0.781 | .750 | .963 |
| | 3 x 2 x 1/8 | 0.844 | .840 | .994 |

Fig. 3 — Structural efficiency index, bending.

in performance, which can only be overcome by other means such as increased engine output, meaning a heavier engine. This in turn may require an increase in weight of the structure supporting the engine, in order to carry the heavier engine. It is not unusual, therefore, to experience an overall weight increase of seven to 15 times the actual weight increase of the original component.

Closely associated with weight in the designs of today is available space. In the modern aircraft or missile there is practically no unused space within the aero-dynamic shape or shell. Any significant change in shape of a component usually results in a change in external shape, elimination of some other component, or compromise in function. This means that even in those cases where the weight increase may not be objectional, loss in aerodynamic efficiency or performance of some other part will prohibit a change in size or shape of a component.

This factor is more important in proposed design changes than in the original design, since it is assumed that the original design encompassed the above considerations. However, it will still influence to a certain degree the design freedom in the original concept.

### Design Requirements

To meet the weight and space requirements the aircraft designer must utilize more complex shapes and maintain closer adherence to optimum structural shapes than is generally necessary in other industries. This is reflected in two ways, 1) the designs are usually based on ultimate strength not proportional limit or yield strength; and 2) the margins of safety rather than factors of safety are used. This means that many short cuts, compromises and tolerances which may be common in a majority of the commercial applications will be unacceptable to the aircraft designer. It also requires the use of different design parameters.

For example, if a member to carry bending is desired, an analysis of the many possible shapes will be made. A summary of a few of these is illustrated in Fig. 3. Where a general designer might be able to use the third column as a guide, since this number is a measure of the load carrying ability, the aircraft designer must be guided by the fourth column which is a measure of the strength-weight ratio. This figure is by no means complete nor does it consider all possible modes of failure, it assumes failure will occur in tension at the outermost fiber.

To obtain a complete evaluation such items as complex loading or bi-axial stresses, buckling and crippling must be taken into account. The aircraft designer must go through all of these factors, as well as repeating the same type of analysis for the other major types of loadings, in order to arrive at the optimum design.

The loading breakdown of a typical aircraft design must be known in order to realize the relative importance of the various mechanical properties which govern the design of a component. In a typical design the breakdown may be as follows—shear 37 per cent; bending 23 per cent; compression 21 per cent; and

tension 19 per cent. The actual percentages might vary significantly from one design to the next, but the general order of magnitude will probably remain fairly constant. It should also be noted that this breakdown is based on the critical loading for each component, and many of them are subjected to more than one type of loading at any given time.

In most cases fatigue has not been a major factor, but this is closely associated with the design function of the aircraft. For example a transport or passenger aircraft would be much more prone to be critical in fatigue than say a military fighter, and a ballistic missile would probably have no fatigue problems. Wherever fatigue is a factor, the major consideration is that endurance limit is not the criteria to use. What will be important is the life of a part at high stress levels, that is in the finite life region rather than infinite life.

In summary, the aircraft designer will be searching for a material and a process that will meet his design objectives. In order to do this he will require a part which will meet certain minimum strength requirements, with closer tolerances than are generally needed in other industries. He will not be as willing to compromise as his counter part in other industries, but he will be willing to pay a greater premium for the attainment of his objectives than his counter part.

## CASTING REQUIREMENTS

The first item that comes to mind as a requirement for aircraft steel castings is high strength, or the ability to retain its strength at elevated temperature. Although this will be essential to the efficient utilization of steel castings by the aircraft industry the primary requirement is more basic. Before the above can even be evaluated properly the problem of reproducibility must be resolved. As pointed out earlier the aircraft applications do not permit the use of large factors of safety to allow for any significant variation in properties.

There are several instances today where castings were originally designed into the structure but eventually were not used because of the inability of the foundries to produce a uniform product from heat to heat. Usually by the time sufficient design factors were incorporated in the design to account for the observed variations, the part had become too large to fit into its proper place or so heavy that a non-ferrous material could be used with improved strength-weight ratio.

Over the past year a statistical sampling plan has been in operation at the author's company to evaluate the mechanical properties of production heats of castings. The normal procedure followed to place a production order was to release the design for procurement of a qualification heat of castings. This order required the castings to be of a certain alloy and have minimum strength requirements in addition to dimensional requirements. In several cases negotiation with the foundries produced several changes in the original requirements. Once agreement was reached, the first lot of castings was produced and delivered.

This lot was dimensionally inspected, and then tested in a jig simulating the actual airplane structure and loadings, as well as by conventional tensile test coupons

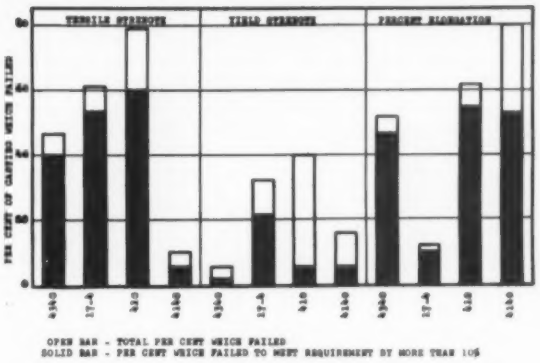


**Fig. 4 — Per cent of castings which failed to meet minimum strength requirements.**

cut from the castings. The jig test was then corrected to the minimum strength level and compared to the design requirements. In several instances this procedure was repeated since the above evaluation disclosed design errors as well as strength deficiencies in the casting. Once the casting passed the above qualification, production orders were placed. The sampling plan was then used on castings procured in this manner. The results are shown in Fig. 4.

The picture that evolves is discouraging to say the least, particularly when follow-up action has disclosed the reasons for these failures. In some cases melt practice was changed, heat treatment procedures were varied, raw material sources were changed, gating and risering was changed, mold composition was changed and pouring and tap temperatures were varied. In most cases the changes were made with a sincere desire to improve the product either economically or strength wise. The fact remains, that the effects of these changes were not always known, and in cases where they were it was assumed that they would be insignificant.

If the aircraft designs were to have significant factors of safety the changes would probably have resulted in a part which was still usable, but this was not generally the case. In striving to achieve the minimums that the aircraft designer set, considerable time and effort was expended by the foundries in developing improved alloys. Extensive metallurgical and chemical analysis studies, and involved heat treatment procedures were also investigated. This without a question has helped and will be required for the eventual optimization of the castings, but it does not solve the basic problem. Neither will it be possible to properly evaluate these other factors until a uniformity of foundry procedures are achieved.

### Guaranteed Minimum Strength

Returning now to the requirement of high strength, it must be realized that this to the aircraft designer means high guaranteed minimum strength not nearly average strengths. Furthermore, this strength must be achieved on the castings, not on separately or integrally cast test bars. This is not to say that there is nothing to be gained from test bar results, since they must be used effectively for foundry control, but to the casting user they are useless unless the designer wishes to fly test bars. The aircraft designer recognizes that

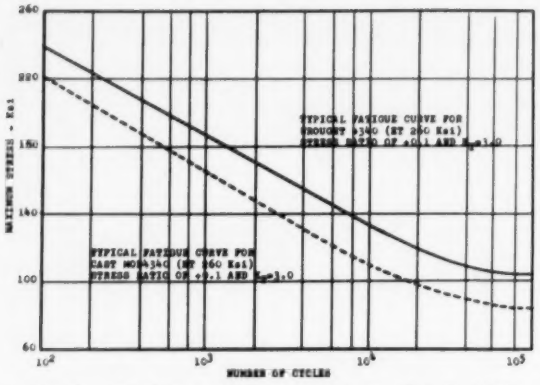


**Fig. 5 — Axial load fatigue strength for S.A.E. 4340 steel. The only significant difference in alloys was the microscopic gas porosity and inclusions. Both of the alloys met existing inspection criteria.**

the problem of establishing minimum strength levels in a complex casting is not simple, but then neither is his problem of guaranteeing the strength level of the aircraft.

## Strengths Desired

Without having minimums for the individual components, it is almost impossible to guarantee the strength level of the aircraft. In the past he has worked with other industries and has obtained minimum guarantees from them, which have been met consistantly, therefore, he is expecting the foundries to do the same thing.

As pointed out earlier the strength desired by the aircraft designer is not always tensile. In most cases the criteria will be shear, bending or compression, and unless these other properties have been proven to have a fixed relationship to the tensile properties they also must be evaluated. In many cases castings are rejected because the tensile properties are a few per cent below the requirement. To the foundry this appears unreasonable since the deficiency is practically insignificant, and if the casting were critical in tension only, this might be true. However, unfortunately few parts will remain critical in the manner designed if other properties are reduced.

A simple illustration of this would be a case where a casting was rejected due to the elongation being five per cent rather than six per cent as required. If the part were critical in tension only it is highly doubtful that this reduction would make the difference between a good and a bad part. Assume, however, that this reduction was due to small inclusions or some other similar defect too small to be picked up by x-ray or other conventional inspection procedures. What would this do to the fatigue strength? A good example of this is illustrated in Fig. 5. This means the aircraft designer is faced with a decision not of a few per cent deficiency in elongation but a reduction in fatigue strength many times greater.

The need for elevated temperature strength is fairly obvious when the aircraft requirements discussed previously are considered. Steel castings capable of being used at temperatures up to 1000 F must become common place, and casting alloys for use at 1000 to 2000 F must be developed. The next question might be what strength levels are required? The only possible answer at the present is that they must be as high as possible. When the present missile designs are examined it will be discovered that the pay load is usually five per cent or less of the total weight.

Any increase in strength realized in the structural components will permit a significant increase in this pay load by reducing the weight required for these structural components. This permits heavier pay loads to be carried without requiring a new family of missiles to accomplish the job, and allows higher performance with the lower pay loads.

## Two Important Factors

Two factors must be kept in mind when attempting to get these high strength levels at the high temperatures. First, the other properties such as compressive strength and fatigue strength must be kept at approximately the same relative position to tensile strength as they are at room temperature. This is necessary in order to avoid any major changes in design concepts. If it is not possible to do this, then the aircraft designer must be informed so that the basic design concepts can be modified accordingly.

Second, the properties at room temperature must be kept at reasonable levels. This latter item is mentioned since there have been several instances where desirable elevated temperature strengths have been obtained, but the room temperature ductility has been reduced to practically zero. Since the aircraft or missile must at least start its flight at relatively low temperatures and carry significant loads at the same time, it must maintain some reasonable load carrying ability at the lower temperatures.

Associated with the problem of strength at temperature is that of time at temperature. In a missile where the total life may be measured in minutes, the desired criteria would be completely different than for a transport or passenger airplane where the life desired may be several thousand hours. This means there will be widely varying needs by the aircraft designer depending on the type of design on which he is working. Most of the work done up to the present deals with properties associated with long exposure time.

The properties most urgently needed are those for short exposure times, from a few seconds to some one or ten hours. Creep properties for total deformations of less than one per cent are also needed. In addition, fatigue strengths at temperature using practical stress raisers for life on the order of one to 100,000 cycles are needed since most published data deals with the longer life region.

## Loading Importance

One other factor which has assumed an important roll is rate of loading. There are many applications where a particular casting was not considered due to its reportedly low strength. Closer examination revealed that the strengths reported were based on relatively slow loading rates. When the material was tested at loading rates simulating the design load rates it proved to be satisfactory. Since these loading rates will vary quite widely depending on the design it is almost impossible to predict what value should be used.

In general, the rates used should be increased as

much as possible to obtain data at faster load rates than are commonly used today. The important item is to record loading rates not strain rates, and include this information with the reported strength data. In any case, more information is needed on the effect of loading rates on the strength of the castings and casting alloys to enable the aircraft designer to use them.

In establishing tolerance requirements it is not just a matter of making parts fit together and within a given envelope, but also a matter of weight. Studies conducted on existing aircraft have disclosed that due to tolerance allowables the average weight of the airframe has increased over the nominal by as much as ten per cent. This is readily understood when it is recognized that each process operation on a part is going to be established on the high side of the tolerance range. For this reason the aircraft designer is going to be striving for the closest tolerance ranges possible.

### Optimum

The optimum is going to be a balance between what is possible by the casting process and what the aircraft designer is willing to pay. What makes this problem of compromise difficult is to have the foundry demand its usual tolerance of $\pm$ 0.005 in./in., and then produce a part with less than one half of this spread and refuse to back down on the original tolerance spread on follow-up orders. For example, a part with a 15 in. dimension would have a tolerance of $\pm$ 0.075, yet when produced by the foundry the spread from one casting to the next over 15 heats was on the order of $\pm$ 0.025.

Perhaps the solution would be to recognize that the tolerances requested by the foundries at the present cover two items, 1) the possible variation from one part to the next due to the normal process variations, and 2) the error involved in estimating shrinkage in constructing the pattern. If this were made clear to the aircraft designer, then a compromise could be reached on how much he is willing to pay for pattern rework, to reduce or eliminate the latter of the two sources of tolerance build up.

Finish requirements are going to vary widely depending on the design function of the part. In general, due to the nature of the casting applications, the requirements are going to be as rigid if not higher than for a majority of the other structure. Basically, a finish from 125 to 250 rms will be sufficient. Where better finish is required provisions should be made for machining or polishing, unless the casting process will normally produce a better finish. The finish is a source of many arguments as pertains to fatigue life.

If it is considered that all components must be joined to each other, and that this junction is usually formed by putting holes in the part and using fasteners, the stress concentrations due to surface finish become less important. It has also been found that for most alloys presently used, the effect of nominal changes in surface finish do not significantly affect the fatigue life of the parts at high stress levels, rather they affect the fatigue life at low stress levels. Since the aircraft designer is primarily concerned with high-stress low-life fatigue, the surface finish, within limits, assumes a secondary role.

In any case, if the surface finish of 125 rms could be maintained, the castings would be competitive with other fabrication processes. This should not be considered the ultimate goal but merely a guide, since there already are casting processes which will give better finish than this.

### Uniform Specifications Needed

Finally, the most important requirement is going to be a set of uniform and rigid specifications to govern the production of the aircraft castings. Based on experiences in other industries it is going to be necessary to establish a set of specifications for general or commercial products, and a separate specification for aircraft or high quality products. This has been done in the other industries but not in the casting industry. Here the aircraft industry is being asked to buy castings that do not meet any basic minimums. This is not possible to do, and utilize castings as completely as the aircraft industry would like to do.

Once an alloy having desirable mechanical properties and acceptable casting qualities has been found a specification for it should be written. This is not always the same composition or necessarily the same properties as the wrought alloy. This specification should govern such things as compositional limits, strength limits and those process variables which affect the strength levels as well as establish sampling procedures for evaluating these properties.

Since the foundry industry has not produced these necessary specifications many aircraft companies have a set of casting specifications, supposedly for the same alloys. This produces an even greater amount of confusion than is already present. In each case, based on the experiences with the individual design involved, the specifications are modified to produce the optimum for that design. This means that each specification tailors the alloys and casting to meet some specific design requirement.

Unless by some chance the original alloy and configuration were optimum from all points of view this procedure will eventually lead to as many specifications for a given alloy as there are design applications. This is not necessary, nor is it desirable from the viewpoint of the aircraft designer or the foundry. All that is required to reduce or eliminate these various specifications, many of which conflict with each other, would be a set of specifications from the foundry industry guaranteeing minimum properties for the steel castings.

### Setting Up Specifications

In setting up these specifications it must be recognized that the existing inspection criteria are not adequate for evaluating the aircraft steel castings. Essentially they will reject those castings having obvious defects, but those which pass are not necessarily good. In a test program conducted by the author's company a total of 114 specimens from 14 heats produced at 3 foundries using a modified S.A.E. 4340 alloy were inspected and tested. Basically, the specimens consisted of standard 0.505 in. round tensile specimens machined from keel blocks. A fairly simple form to pour, and certainly an easier part to inspect than the average casting.

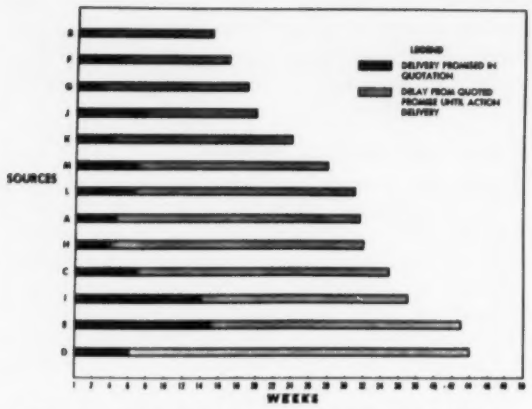


Fig. 6 — Foundry performance showing quoted delivery vs. actual delivery of castings.

These specimens were subjected to the normal inspection criteria required by existing military specifications as well as other applicable casting specifications by both the foundry quality control personnel as well as company engineering personnel. These bars met all the requirements such as x-ray, dye check, fluorescent penetrant, Rockwell, Brinell, etc. However, 15 per cent of them failed at loads significantly below the general level and sometimes at less than 30 per cent of the average. If the specification criteria were disregarded and all bars showing some irregularity, particularly in x-ray, were thrown out, half of the low values would be eliminated.

This still leaves approximately seven to eight per cent which cannot be detected. If actual castings were used instead of test bars, than the numbers would probably be more like those indicated in Fig. 4. The above study was made specifically to check the existing specification criteria without introducing shape or complexity as a factor. Granted the data is far too limited to draw firm conclusions, but certainly the indications are strong that a re-evaluation of existing specification criteria is necessary for aircraft quality castings.

## FOUNDRY REQUIREMENTS

To achieve these casting requirements several factors involving foundry practices and procedures must be recognized. The first of these is process control. It is logical to expect that an improvement in quality of the product can only be achieved by improvement in process controls. Since the aircraft designer is asking for a higher quality casting than the general commercial casting, it follows that the process controls utilized for a commercial casting must be improved, when used on aircraft castings. In many instances this merely means closing up of the tolerances allowed. In other cases it may require a whole set of new controls.

An example of this encountered by the author's company was a program conducted to produce a high alloy steel casting. The original efforts by three foundries resulted in parts for which the strength levels varied from 160,000 to 230,000 lb/sq in. The first efforts by the foundries to improve this situation was by variation of composition, improved heat treatment procedures and the like These efforts raised the average result but did not change the relative magnitude of the scatter.

When, at the request of the company, the process variables such as melt practice, pouring temperature and pouring time were controlled as much as was practically possible, the range was reduced to 180,000 to 200,000 lb/sq in. for the original alloy. In other words, mechanizing the process as much as possible increased the minimum strength by a greater amount than was possible with the metallurgical, chemical and heat treatment variations.

When the latter improvements were then added to the improved process the final result was an alloy with a minimum strength of 210,000 lb/sq in. and a scatter of only 20,000 lb/sq in. The interesting thing is that this was accomplished at no significant increase in the cost of the casting.

The second factor which must be considered is time. In order to keep up with the advances in the aircraft industry, and in the military field to maintain the national defense status, the time required to produce an aircraft or missile has assumed a major role. All operations involved in producing the final product must be accelerated. In order to meet these accelerated demands all processes must be expedited. In this respect, the experiences of the aircraft industry with the foundry industry have been poor. Figure 6 presents a summary of the performance experienced by the author's company over a period of time.

Two things must be improved, 1) the time lapse between promised delivery and actual delivery must be reduced or eliminated, and 2) the time required for actual delivery must be reduced. This need becomes evident when it is realized that there are aircraft designs which must be completed within a time span comparable to the times required by the foundries to produce one component of the design. The greater the time required by the foundries to produce a casting, the less chance there will be of using the casting. It has been estimated that if the times required by the foundries could be reduced to half that shown in Fig. 6, at least three times as many castings would have been used in the same time interval.

### Cost Performance

Closely associated with the time element is the cost performance. Essentially the cost performance has been almost an exact duplicate of the time performance indicated above. Basically, then, a need exists for accurate cost and scheduling procedures as well as an accelerated schedule in most cases. The major fault to date, appears to be the lack of distinction between the commercial and the aircraft castings by the foundry. The two price structures are bound by necessity to be different.

A third factor that must be considered is not too easy to define. For lack of a better name it can be referred to as progressive thinking. The best example of this is a casting design recently attempted by a foundry. The foundry was given a drawing showing the nominal dimensions required for the final part and asked to cast the part as close to this as they could. The idea was to obtain a final part requiring a minimum of machining. The foundry would also be permitted to make any

changes required as they progressed to achieve this goal. The nominal weight of the part was 110 lb.

The resulting casting produced by the foundry weighed 213 lb, or it means that almost as much material would have to be machined away as the total part weighs. The argument used was that they first wanted to produce a sound casting and then gradually remove material where they could. At this rate it is easy to see that economic considerations would probably stop this procedure long before the optimum were reached. At the insistence of author's company a second pattern was made to the nominal dimensions and castings poured.

This part weighed 123 lb, due to the pattern being at the upper side of the tolerances given to the pattern maker and one or two changes that were obviously needed. In a like number of trials, and at approximately the same cost as before, a final part has been obtained that weighs 133 lb.

When it is considered that most of the castings required by the aircraft designer are going to be of alloys which are difficult and expensive to machine, the importance of keeping the part to a minimum cannot be over emphasized. It seems a shame to produce a casting which will cost more to machine than to cast. Consider also that the casting is competing not against a forging or an extrusion but against these forms plus machining. Any machining eliminated is, therefore, just that much more money that can be directed to obtaining a sound casting. Every effort, within reason, must be made to cast the final shape desired and avoid the middle man, or machining, as much as possible.

The final factor that must be considered is that the aircraft industry will never become a large tonnage customer to the foundry industry. However, it can and will become a large dollar customer. The aircraft designer will be willing to pay for the part and quality that is required, not just purchase steel at so much a pound. As the foundries gain confidence in their ability to reproduce results, and guarantee performance, this situation should change rapidly.

## SUMMARY

In summary, the immediate requirements for quality steel castings in the aircraft industry are as follows:

1. High strength steels capable of operating at temperatures as high as 1500 F.
2. Reproducibility of results.
3. Guaranteed strength levels.
4. Adequate inspection criteria.
5. Improved tolerances.
6. Improved cost and time estimates.

An analysis of these requirements reveals that they are goals which should be common to both the foundry industry and the aircraft industry. Therefore, with a sincere effort by both to achieve these goals, and with an understanding of each other's problems and limitations, there is no reason why these goals cannot be attained to the mutual benefit of both industries.

# GRAIN REFINEMENT OF SOLIDIFYING METALS BY VIBRATION

By R. G. Garlick and J. F. Wallace

## ABSTRACT

A number of different liquid metal compositions, including pure metals and alloys that solidify as solid solutions and eutectics, were vibrated under controlled solidifying conditions. Metallographic examination of the solidified ingots of these metals indicated that all were grain refined to some extent, although the amount of refinement varied considerably. The grain refinement increased for those metals exhibiting the larger solidification contraction. Data in technical literature generally confirmed this finding.

This latter fact provides substantiation of the theory that vibration, with its alternate high and low pressure waves, increases the nucleation rate of the solidifying phases. Mechanisms that describe how this grain refinement is caused by vibration during the solidification of pure metals, solid solutions and anomalous eutectics are discussed.

## INTRODUCTION

Previous investigations have established that vibrations applied during the solidification of molten metals will result in degassing and a finer as-cast grain size. The amount of grain refinement, however, has been reported to vary considerably for different metals, and various frequencies and amplitudes of vibration. The grain refinement of pure metals,[1,2] solid solutions when present in a single phase alloy,[2-7] and metals or solid solutions when present as the hypo- or hypereutectic phase,[1,3,6-9] has been shown by the references listed for each.

The behavior of eutectics solidifying under the influence of vibration is considerably different. It has been reported that the eutectic constituents, particularly the minor eutectic phase, coarsened under the action of vibrational energy.[3,4,5,8]

Two theories have been offered to explain these effects of vibration on solidifying melts. The first theory postulates[1,9,10] that the grain refining effect of vibration is produced by fragmentation of primary crystals or dendrites, thereby providing an artificial source of stable nuclei. This fragmentation has been attributed to the high pressure cycle following cavitation,[1] or the viscous forces acting on the dendrites or crystals.[9,10] The second hypothesis explains this effect as an increased rate of nucleation produced by the alternate pressure and rarefaction waves in the melt.[4,5]

This latter hypothesis assumes that introducing vibrational energy into the melt will produce these alternate waves of high and low pressures. The existence of these moving or stationary waves (depending upon size of crucible, method of introduction, frequency, etc.) is generally accepted in the literature.[1,3-5,7-11] This latter theory when fully developed[4] is capable of explaining both the grain refinement of primary crystals and dendrites and coarsening of eutectic constituents that have been observed as a result of vibration.

The fragmentation theory, however, is incapable of explaining this coarsening of eutectic constituents and, therefore, does not appear to be justified, particularly since the phases refined are more ductile than those coarsened.

However, it should be noted that the influence of vibration on solidifying metals can be affected by several factors. These include—the peak to peak displacement of the vibrational energy in the melt, the amount of superheat of the metal when poured, the temperature of the mold, the rate of cooling in the mold and the presence of grain refiners or inoculants in the melt. The influence of the vibrational frequency and method of introducing the vibrational energy or grain refinement has been a subject of considerable disagreement.

### Vibrational Energy Effect

There is considerable evidence[4,5,9] that if sufficient peak to peak displacement is obtained in the vibrations introduced into the melt, that the frequency and method of introduction is of small consequence. It has been shown, however, that the amount of grain refinement of primary dendrites and crystals[5,8,9] and coarsening of eutectics[8] is increased with greater energy on peak to peak displacement up to a certain point before attaining a maximum and becoming fairly insensitive to further increases.

In order to obtain the full influence of vibration, it is necessary that the vibrational energy have sufficient opportunity to act upon the solidifying melt. Accordingly, if the rate of solidification is too rapid, because of a cold mold or insufficient superheat, little influence will be observed.[5,8]

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This work reported herein represents a portion of an M. S. Thesis submitted to Case Institute of Technology by R. G. Garlick.

TABLE 1 — CHEMICAL ANALYSES OF VARIOUS METALS AND ALLOYS INVESTIGATED

| | Al | 12% Si Al | 4½% Cu Al | Brass | Mg | Zn | Gray Iron | Bi | Sb | Sn |
|---|---|---|---|---|---|---|---|---|---|---|
| Cu | | 0.10 | 4.51 | 64.56 | | | | | | |
| Al | bal. | bal. | bal. | <0.05 | 0.02 | 0.25 | | | | |
| Si | 0.14 | 12.18 | 0.28 | | | | 2.56 | | | |
| Fe | 0.03 | 0.49 | 0.28 | 0.02 | 0.02 | 0.002 | bal. | | | |
| Zn | | 0.40 | 0.20 | 35.35 | <0.02 | bal. | | <0.05 | <0.05 | <0.02 |
| Mn | | 0.27 | <0.02 | | | | | | | |
| C | | | | | | | 3.44 | | | |
| P | | | | | | | 0.087 | | | |
| S | | | | | | | 0.074 | | | |
| Ti | | | 0.008 | | | | | | | |
| Pb | | | | | | 0.005 | | 0.001 | 2.25 | 0.01 |
| Sn | | | | <0.05 | | <0.001 | | 0.50 | 0.80 | bal. |
| Sb | | | | | | | | 0.01 | bal. | 0.02 |
| Bi | | | | | | | | bal. | 0.06 | 0.01 |

A theory was proposed to explain the influence of vibration on the grain size of the constituents in a solidifying melt.[4] This theory was developed as a result of prior work conducted under the sponsorship of Rodman Laboratory, Watertown Arsenal. In brief, this hypothesis stated that the alternate high and low pressure waves generated in a solidifying melt reduced the size of the critical nucleus necessary for solidification, thereby reducing undercooling and increasing the rate of nucleation.

The pressure wave favored the formation of solid when the solid was more dense than the liquid, and the rarefaction wave would favor the solid when less dense than the liquid because of the Le Chatelier-Braun principle. The former is, of course, the usual case. This theory further states that the rate of growth of the stable nuclei must be sufficiently rapid to permit these to exceed the critical radius for the wave of opposite magnitude.

This investigation was undertaken to provide further data that would substantiate or disprove this theory. In the course of this work, pure metals, and melts which solidify as solid solution and eutectics, were melted and vibrated under closely controlled conditions. If the theory advanced is correct, the amount of grain refinement attained by vibration should be influenced by the difference between the density of the liquid melt and solid metal immediately after solidification. For this reason, metals and alloys that exhibited a considerable range of solidification contraction were selected for this investigation.

## PROCEDURE

The metals and alloys that were studied are listed here according to their mode of solidification.

| Pure Metals | | Solid Solutions | Eutectics |
|---|---|---|---|
| Aluminum | Magnesium | Aluminum-4.5% Copper | Aluminum-12% Silicon |
| Antimony | Tin | | |
| Bismuth | Zinc | 70% Copper-30% Zinc | 4.20% Carbon equivalent gray iron |

The composition of each metal is listed in Table 1. All pure metals were purchased as commercially pure ingot. The solid solution materials were melted from commercially pure ingot. The eutectics were 13 alloy for the Al-Si, and commercial, eutectic composition gray iron.

The aluminum, aluminum-base alloys, and the gray iron were melted in an acid-lined 10kc, 10kw high frequency induction furnace. The other metals were melted in separate clay-graphite crucibles in a gas-fired furnace. Only the magnesium metal was fluxed during melting. No degassing was conducted. To avoid masking the effect of vibration, no inoculants or grain refiners were added to any metal.

All metals were superheated to 200-300 F over the melting or liquidus temperature immediately prior to pouring, to permit a reasonably slow rate of solidification. Temperature measurements were taken with immersion thermocouples.

### Metal Pouring

The metals were poured directly from the melting crucible into a smaller, tapered, clay-graphite crucible used as an ingot mold. These crucibles or molds were heated to approximately 700 F by means of a gas torch before pouring, for all except the lower melting temperature metals (tin and bismuth). The preheating was necessary to prevent rapid solidification. Each melt was split into either two or three equal portions, and each portion was poured into similarly preheated molds.

Each ingot poured was approximately 4 in. in diameter, 5 in. high (63 cu in.). The molds were bolted securely to a metal plate by means of steel clamps. Several series of ingots were poured for each metal.

Vibrations were applied to the solidifying melts by two methods. All metals were subjected to 60 cycle/sec vibrations by bolting one crucible to a metal table mounted over a 300 lb force output electromagnetic vibrator. The arrangement of the crucible on the 60 cycle vibrator is shown in Fig. 1. In addition, the aluminum and zinc were subjected to vibrations from a probe inserted into the melt through the top surface, as shown in Fig. 2. The probe was coupled to a 20kc, 110 watt magnetostriction generator.

The coupler used for vibration of aluminum was a ⅞-in. diameter titanium rod, wetted with aluminum metal before use. A 310 stainless steel ⅞-in. diameter coupling rod was employed for the vibration of zinc.

The molten metal from the induction furnace or melting crucible was poured into two crucibles when only 60 cycle vibration was employed, and into three crucibles when both 60 cycle and 20 kilocycle tech-

niques were utilized. In each case, one crucible was held statically to serve as a control ingot cast under similar conditions for comparison with the vibrated metal. The 60 cycle vibration was started before pouring each ingot. The ingot vibrated at 20kc was poured first, and then the vibrating probe introduced through the top surface of the melt.

This investigation was designed to explore the mechanism of grain refinement by vibration rather than to develop refinements in the technique. Accordingly, when it was established that approximately the same result was obtained with each type of vibration, the majority of the experiments were performed by the 60 cycle method. This latter technique is easily performed and controlled to assure uniform treatment.

Thermocouples were inserted in the approximate center of each ingot during the vibrating and solidification period. These thermocouple wires were contained in two-hole refractory insulators, but the hot junction was bare to provide direct contact with the solidifying melt. Chromel-alumel couples were used for all except the gray iron; platinum - platinum with 10 per cent rhodium was employed because of the higher melting temperature of this latter metal. Cooling curves were recorded on potentiometers throughout the period of cooling and solidification.

After the ingots had cooled to room temperature, they were removed from the crucibles and sectioned longitudinally. The longitudinal surfaces were polished and etched by suitable techniques to develop the grain structure. An area that was representative of the grain size of the ingot was selected and the number of grains determined within this area. Similar locations were selected when comparing the control and vibrated ingots of each metal. In the case of the ingots with a columnar structure, it was necessary to determine the number of grains intercepting a line and convert this to an area measurement.

Fig. 1— 60 cycle vibrator and ingot mold arrangement.

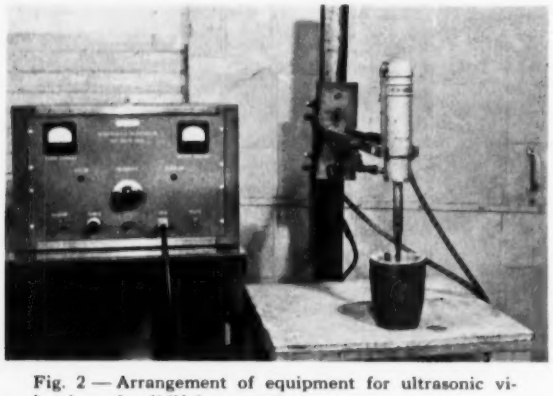


Fig. 2 — Arrangement of equipment for ultrasonic vibration of solidifying metals.

TABLE 2 — GRAIN REFINEMENT FOR VARIOUS SOLIDIFICATION CONTRACTIONS OBTAINED IN THIS INVESTIGATION

| Metal or Alloy | Mode of Solidification | Solidification Contraction, % | Grains/Unit Area — Vibrated Grains/Unit Area — Unvibrated |
|---|---|---|---|
| Zinc | Pure metal | 6.5 | 60 |
| Aluminum | Pure metal | 6.5 | 110 |
| Magnesium | Pure metal | 4.2 | 8 |
| Tin | Pure metal | 2.7 | 12 |
| Antimony | Pure metal | 1.4 | 1.8 |
| Bismuth | Pure metal | —3.3 | 2.3 |
| Al — 12% Si | Eutectic | 3.8 | 3 |
| Gray Iron | Eutectic | —1.5 | 1.5 |
| Al — 4½% Cu | Solid solution | 6.3 | 77 |
| Brass | Solid solution | 5.5 | 17 |

## RESULTS AND DISCUSSION

The grain refinement obtained by vibration of each of the prime metals, solid solution and eutectics is shown in Table 2. This table lists the mode of solidification of the metal or alloy, amount of solidification shrinkage obtained with this material and a ratio of the number of grains contained in a given area of the vibrated ingot compared to the number of grains contained in a similar area of the unvibrated or control ingot.

In order to demonstrate the influence of vibration on the grain refinement of the pure metals, photomacrographs of representative, etched halves of the control 60 cycle and 20 kc vibrated ingots for aluminum and zinc are shown in Fig. 3. The macroetched ingots for the other commercially pure metals, antimony, bismuth, magnesium and tin, in the vibrated and unvibrated condition are shown in Fig. 4. The vibrated and control macrostructure of the alloys that solidify as solid solutions (Al-4.5 per cent Cu and 70 per cent Cu-30 per cent Zn), and the microstructure of the eutectics (Al-12 per cent Si and gray iron) are illustrated in Figs. 5 and 6, respectively.

In this latter case (Fig. 6) the eutectic cells were considered to be individual grains. The structure was so fine that microexamination is required to show the influence of vibrations on eutectics. Attention is called to the coarser eutectic constituents which accompany the finer cell structure of the vibrated ingots. The reason for this structure was previously described.

According to the theory that was postulated,[4] vibrations introduced into a solidifying melt would increase the rate of nucleation of solid phases in this melt because alternate high and low pressure waves are produced in the liquid. The high pressure wave would favor the existence of the most dense state, usually the solid state. The low pressure wave favors the lower density state, usually the liquid, but in some instances the solid, state.

It is also necessary to postulate that any stable nu-

Fig. 3 — Macrostructures of zinc (top row) and alumnimum (bottom row) ingots vibrated at 20 kc (left), 60 cycles (center) and unvibrated (right). Etched. 0.5 ×

cleus existing at a pressure wave would have to grow sufficiently rapidly, so that the critical nucleus size for the following wave of opposite pressure was exceeded before this latter wave reached this location.

If a series of experiments were conducted in which the significant variables for grain refinement were maintained within close limits, the theory previously postulated[4] predicts that the amount of grain refinement would be dependent on the difference between th density of the liquid and solid metal at the solidifying temperature. The known significant variables influencing the effect of vibration on grain refinemet were held reasonably constant in this investigation, and the effect of vibration under these controlled conditions was observed on numerous metals.

The resulting grain refinement of these pure metals, solid solutions and eutectics is plotted vs. per cent of solidification contraction in Fig. 7. In this graph, the amount of grain refinement or number of grains in a given area of the vibrated ingot, divided by the number of grains in a similar area of the control ingot, is shown on a logarithmic scale in order to highlight the metals in which only slight grain refinement occurs.

The data as plotted in Fig. 7 and listed in Table 2 show clearly that the amount of grain refinement under the controlled test conditions is dependent upon the amount of solidification contraction. Only slight refinement was experienced with antimony, and only slightly more with bismuth. Magnesium exhibited somewhat more refinement, 70 per cent Cu-30 per cent Zn still more and a large refinement is shown for aluminum, zinc and Al-4.5 per cent Cu. Tin was refined considerably more than any other metal or alloy with a similar amount of solidification contraction.

Some difficulty was experienced in measuring the grain sizes, but the best approximation is a refinement of one to 12, as shown in Fig. 7 and Table 2. No explanation for this different behavior is offered at this time. The grain refinement increases steadily as the change in volume upon solidification is raised from 1.5 to 6.6 per cent. The effect of vibration on the cell size of the eutectics is also approximately of this same order.

Gray iron, with only a small solidification expansion, is refined only slightly, and the cell size of Al-12 per cent Si with a 3.8 per cent solidification contraction exhibits somewhat more refinement. The refinement of these eutectics represents a special case that will be discussed subsequently.

In order to obtain a comparison of data obtained in this investigation with the other workers in this field literature was reviewed, and the grain refinement reported by numerous investigators were added to Fig. 7.

These refinement figures were limited to publications that either reported the refinement or contained photographs of sufficient clarity to permit these measurements.

Data were limited to those papers that employed no grain refiners and had sufficient energy for refining with enough superheating and mold preheat to allow time for the vibrational energy to act before solidification was complete. The details of the reference work, composition, type of vibration, grain refinement and solidification contraction for all data employed are listed in Table 3. It is noted that all of this work from these several references[1,2,4,5,6,12] agrees closely with the grain refinement vs. solidification contraction information from this investigation.

The thermal data for the most part were unsuccess-

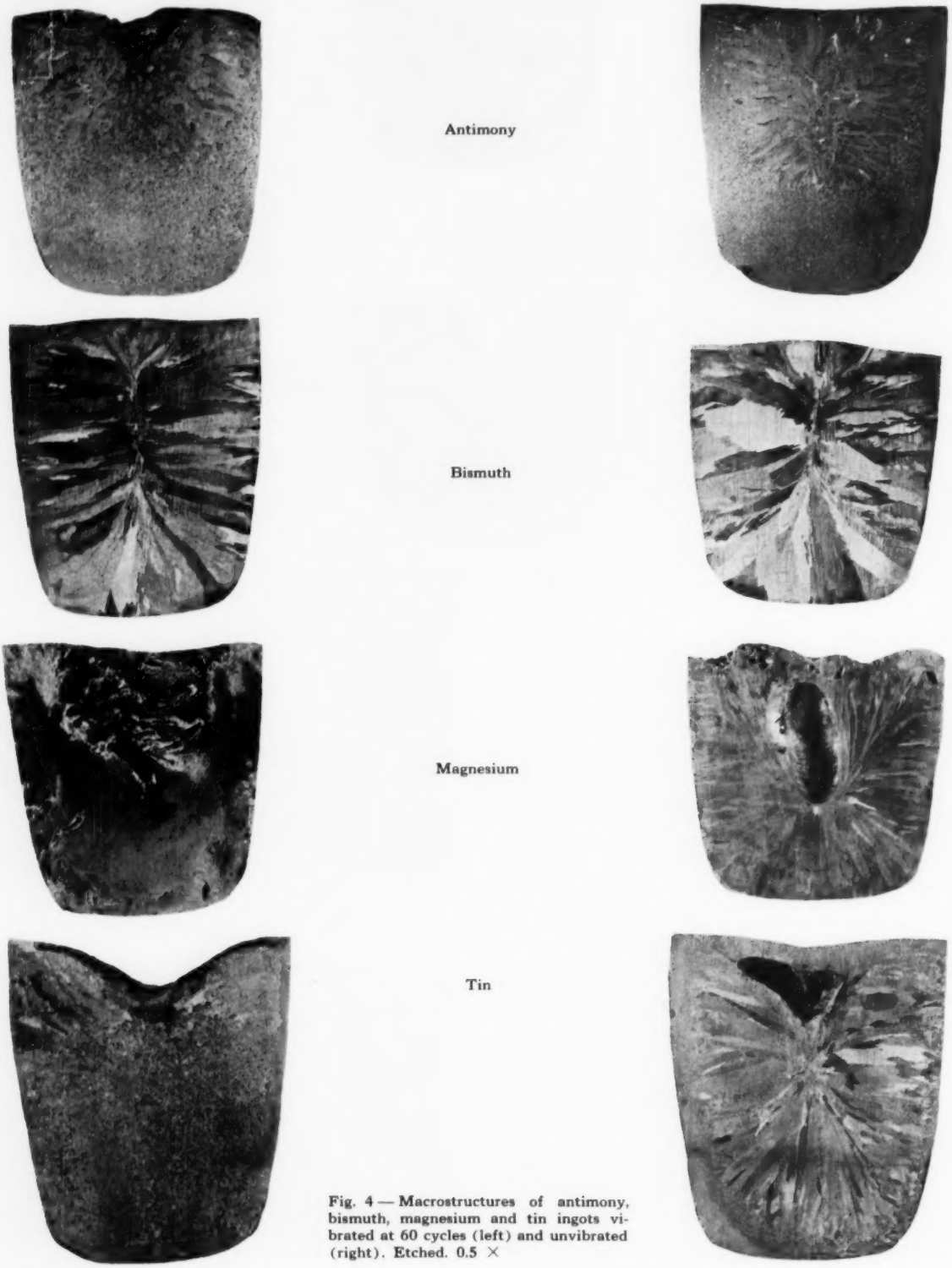
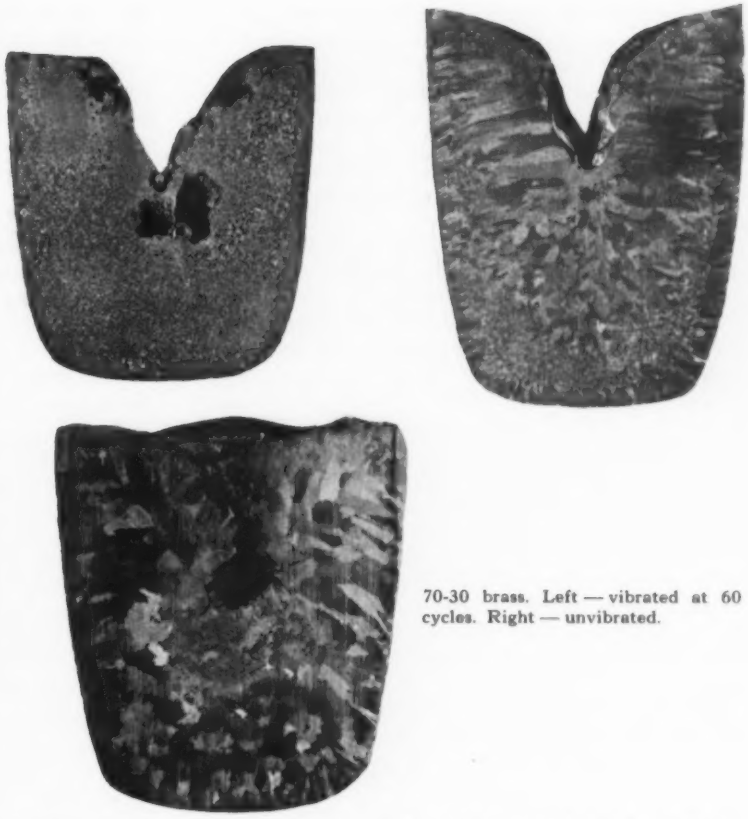



Fig. 4 — Macrostructures of antimony, bismuth, magnesium and tin ingots vibrated at 60 cycles (left) and unvibrated (right). Etched. 0.5 ×



Aluminum — 4.5 per cent copper. Left — vibrated at 60 cycles. Right — unvibrated.

70-30 brass. Left — vibrated at 60 cycles. Right — unvibrated.

Fig. 5 — Macrostructures of aluminum — 4.5 per cent copper, and 70-30 brass ingots. Etched. 0.5 ×

ful in obtaining any consistent difference between the vibrated and control ingots. This condition was attributed to the fact that differences in thermal behavior were so small that it was less than the sensitivity of the thermocouples and instruments. Definite indications were obtained, however, on bismuth, zinc and both eutectics, that the vibrated ingot undercooled somewhat less (2 to 6 F) than the control or unvibrated ingot before solidification was initiated.

The length of time required for complete solidification of the ingots was longer for the vibrated specimens in some cases and the unvibrated ingots in others. No consistent results of longer[8] or shorter[13] solidification times, such as reported in the Russian literature, were observed in this investigation.

## MECHANISM OF GRAIN REFINEMENT

### Pure Metals

Since the metals employed were of commercial purity, it is anticipated that these metals will solidify by heterogeneous nucleation. Even under these circumstances, however, a small amount of undercooling is necessary for stable nuclei to form, so that solidification can proceed.[14] The mechanism by which this solidification occurs to produce the grain refinement observed in pure metals could possibly be explained in a manner similar to solid solution solidification because of the impurities present.

If it is assumed, however, that the metals are of sufficient purity to avoid appreciable concentrations of solute in the liquid metal near the solidifying wall, then another mechanism must be found.

It has been postulated that the thermal conditions during the static solidification of the columnar zone in an ingot of pure metals are shown in Fig. 8a.[14] Figures 4 and 5 illustrate that columnar grains were formed for all the pure metals cast without vibration. These grains were obtained even though the amount of superheat and mold preheat were not conducive to high thermal gradients within the solidifying ingot.

The growth of the columnar grain continues in from the wall, since less undercooling is necessary for continued growth of the columnar grains than for nucleation of new grains and the thermal gradient in the liquid is positive.[14] Under these conditions, the explanation of the grain refinement of pure metals becomes difficult. However, this refinement, as shown in Figs. 4 and 5 of this paper, and in references[1,2] does occur.

It is believed that the thermal gradient in the liquid is not positive throughout the liquid, but that the heat

TABLE 3 — GRAIN REFINEMENT FOR VARIOUS SOLIDIFICATION CONTRACTIONS OBTAINED FROM OTHER INVESTIGATIONS

| Metal or Alloy | Mode of Solidification | Solidification Contraction, % | Grains/Unit Area — Vibrated Grains/Unit Area — Unvibrated | Source |
|---|---|---|---|---|
| Magnesium | Pure metal | 4.2 | 9 | (2) |
| Al — 12% Si | Eutectic | 3.8 | 5 | (4) |
| Al — 4½% Cu | Solid solution | 6.3 | 100 | (5) |
| Brass | Solid solution | 5.2 | 20 | (4) |
| 310 Stainless Steel | Solid solution | 3.0 | 2 — 3 | (6) |
| 1340 Steel | Solid solution | 2.8 | 2 | (12) |

of fusion from the solidifying chill or columnar zone increases the temperature in the immediate vicinity of this solid wall. Once this higher temperature zone is postulated, the grain refining effect or interruption of columnar growth observed in pure metals can be explained. The conditions under which the nucleation of new grains will occur during vibration of a solidifying pure metal with a greater solid than liquid density are shown in Figure 8b.

The pressure wave has the effect of increasing the stability of the solid or denser phase. This means that applied vibrations effectively increase the melting temperature, temperature for continued grain growth and nucleation temperature for new grains. Under the arrangement shown in Figure 8b, the continued grain growth during the high pressure wave is interrupted by the rise in temperature produced by heat of fusion at the solid metal wall.

The high pressure wave increases the nucleation temperature sufficiently to permit nucleation of stable grains in the lower temperature region, as indicated on the figure (8b). Similar conditions prevail for the low pressure wave when the solid is less dense than the liquid. It is doubtful whether as much grain refinement would be anticipated in this latter case, however, since the amount of low pressure is limited by cavitation.

This mechanism of grain refinement of pure metals by vibration depends only upon the slight temperature rise at the solidified wall. It is believed that this temperature rise occurs since pure metals melt at a single temperature. Cooling curves for pure metals generally show this temperature rise as solidification takes place.

**Solid Solutions**

The solidification of solid solutions occurs with a concentration of solute immediately adjacent to the solidifying wall of dendrites. This concentration of solute results in a reduced liquidus temperature immediately adjacent to this wall. These conditions can account for a grain refinement and interruption of the growth of column dendrites when a shallow thermal gradient exists. The solute or impurity concentration, and conditions which favor nucleation of new grains in the melt so that columnar dentritic growth is stopped in a statically cast ingot, is shown in Fig. 9a.[14]

With the sharp thermal gradient $t_1$ columnar dendritic solidification will continue, but with the shallow thermal gradient $t_2$ the nucleation temperature is attained and stable new grains solidify as indicated in this figure (9a). Since these are commercially pure materials, all solidification of these alloys is assumed to be heterogeneous.

Superimposing the alternate pressure and rarefaction waves of vibration upon this system will tend to produce a finer grain sooner or, in other words, will cause a change from columnar to equiaxed solidification with a steeper thermal gradient than in the unvibrated condition. Experimental evidence that this grain refinement does occur is contained in Fig. 5 of this report and in references.[2-7] The mechanism by which vibrations produce this finer, more equiaxed structure is illustrated in Fig. 9b.

The thermal gradient $t_1$ is too steep to permit nucleation of equiaxed grains away from solidifying columnar dendritic wall without vibration. However, both the liquidus and nucleation temperature are raised sufficiently by the pressure waves of vibration so that nucleation of small, stable equiaxed grains occurs at the location shown in Fig. 9b.

**Eutectics**

The somewhat more complicated mechanism by which eutectics solidify has been reviewed in two re-

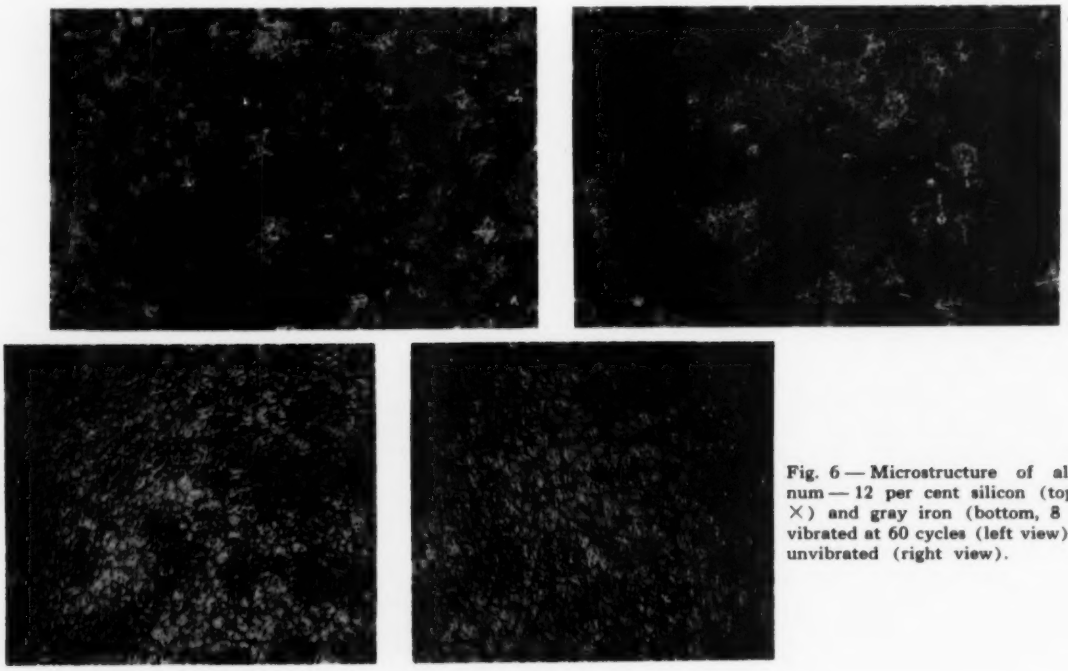


Fig. 6 — Microstructure of aluminum — 12 per cent silicon (top 10 ×) and gray iron (bottom, 8 ×), vibrated at 60 cycles (left view) and unvibrated (right view).

cent publications.[15,16] These alloys are divided into two types—normal and abnormal or anomalous. The primary phase nucleates the secondary phase in the former case. However, the primary phase is unable to serve as nucleating agent for the secondary phase in the analomous type. This seemingly small difference results in substantial deviations in the solidification mechanisms of the two types.

The normal eutectics exhibit a definite crystallographic orientation between the two phases. The anomalous eutectics do not exhibit this regular orientation between the major and minor phases and usually undercool to a greater extent.

This investigation and the other work that has been reviewed are confined to the anomalous type, including the austenite-graphite, Al-Si, Al-$Al_3$ Fe, and Pb-Sb eutectics. In all of these published investigations[3,4,5,8] as well as in this work, it has been shown that vibration will coarsen the eutectic constituents.

In addition, it has been shown in Fig. 6 of this work and reference[4] that the cell or grain size of the austenite-graphite and Al-Si eutectics are refined and the amount of undercooling reduced by this vibration. In view of the fact that experimental data are limited to anomalous eutectics, the discussion of the mechanism of refinement of the cells and coarsening of the eutectic constituents will be limited to this type.

The main nucleation problem, and primary cause for undercooling in the solidification of anomalous eutectics, is the nucleation of the secondary or minor phase.[15,16] Since the primary eutectic phase is incapable of acting as a nucleation agent, foreign nuclei from the melt must provide these sources for heterogeneous solidification.

If the major phase is considered to have been previously nucleated from the eutectic liquid, this solid particle is surrounded by a liquid at a higher temperature than the unaltered liquid eutectic because of heat of fusion and with a higher concentration of the second phase. When this liquid becomes sufficiently supersaturated with the minor phase, nucleation of this phase occurs at a suitable foreign particle. By the application of vibration to this solidifying eutectic, the melting and nucleation temperature of the supersaturated liquid surrounding the major phase is effectively raised in a manner similar to that described for the pure metals and solid solutions.

Vibrations are capable of assisting nucleation of the minor phase immediately adjacent to (although probably not in contact with) the stable nucleus of the major phase. By this action, vibration of a solidifying anomalous eutectic reduces undercooling and increases the number of stable nuclei of the minor phase. This latter action results from the fact that more foreign nuclei are rendered effective by increasing the supersaturation or nucleation temperature.

The effect of vibrating this type of eutectic is similar to inoculation. The number of eutectic cells is increased and the undercooling is reduced. As a result the eutectic solidifies much more slowly than in the static uninoculated state, because the heat of fusion quickly overcomes the slight undercooling and solidification becomes dependent on the rate of heat removal from the ingot. Under these conditions, the eutectic consitituents agglomerate into coarser particles with their reduced surface areas and lower energy state.

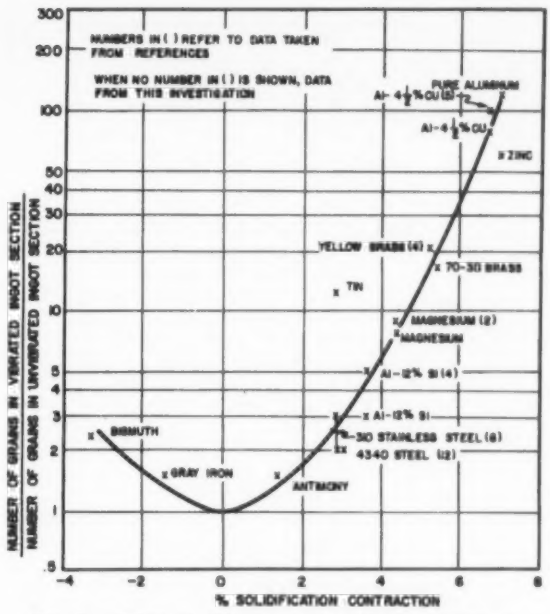



Fig. 7 — Effect of difference in liquid-solid density at melting point on grain refinements resulting from vibrations.

The selection of the significant change in density upon solidification of a eutectic poses a problem. The amount of refinement is measured in terms of the number of eutectic cells or grains. However, the minor phase is generally the difficult phase to nucleate, and it appears that vibration exerts its major influence on eutectic solidification by assisting in the nucleation of this minor phase. For this reason, some considera-

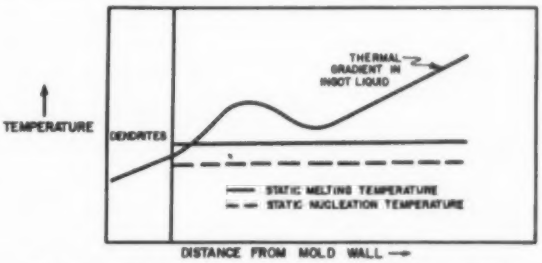



Fig. 8a — Thermal conditions in ingot during solidification of the columnar zone in a pure metal without vibration.[14]

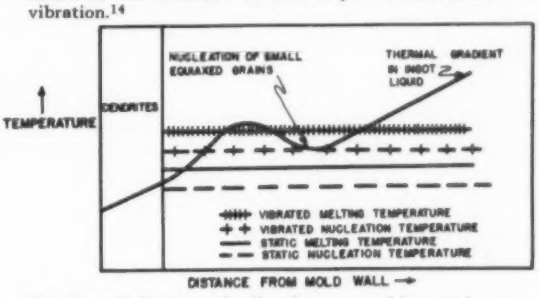



Fig. 8b — Influence of vibration on melting and nucleation temperature in a pure metal and nucleation of equiaxed grains.

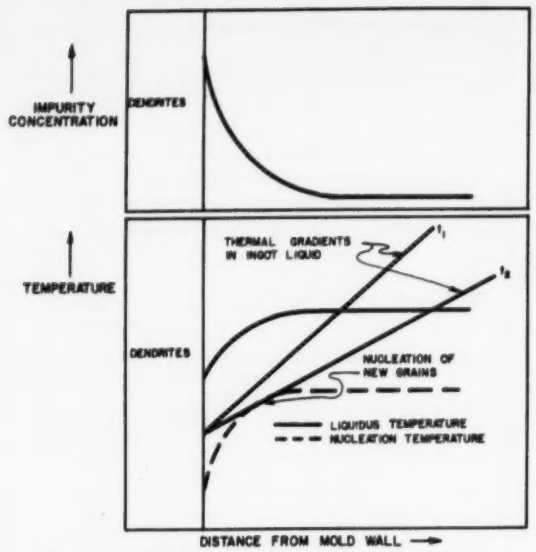



**Fig. 9a — Impurity concentration and thermal conditions during transition from columnar to equiaxed solidification without vibration.[14]**

tion must be given to the significance of the density change involved in the solidification of this minor phase.

It is noted that solidification contraction of the gray iron eutectic varies from a slight expansion to a small contraction, depending on the silicon content. The solidification of graphite from the liquid, however, involves a large expansion. The Al-Si eutectic solidifies with a considerable contraction (3.8 per cent)), whereas silicon solidifies from eutectic liquid with a slight expansion.

In view of the fact that the actual grain size measured is that of the eutectic cells, and vibration undoubtedly contributes to the solidification of the major as well as the minor phase, it is believed that the overall change in volume which occurs upon eutectic solidification is the significant factor. Accordingly, the eutectics are included in Tables 2 and 3 and Fig. 7 with the solidification contraction of the overall composition.

## SUMMARY

By the application of vibration to solidifying metals including pure metals, solid solutions and eutectic compositions, it has been shown that the amount of grain refinement obtained by vibrating a metal or alloy during solidification depends on the amount of solidification contraction. Considerable confirming data have been obtained from numerous literature sources. The establishment of this fact provides substantiation for the theory that the alternate high and low pressure waves of vibration produced grain refinement by increasing the rate of nucleation of the solidifying phases.

The larger the differences in density of the liquid and solid phases, the greater the influence of the pressure waves. The mechanism whereby this increased rate of nucleation can refine the grain size of solidifying pure metals, solid solutions and anomalous eutectics is presented.

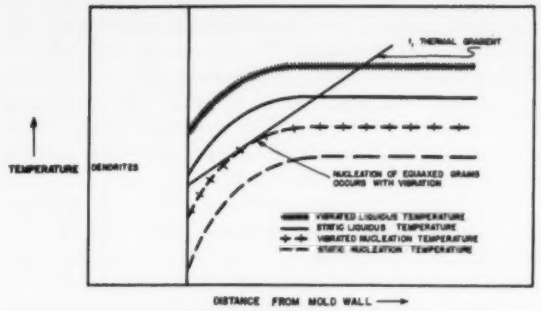



**Fig. 9b — Influence of vibration on liquidus and nucleation temperatures in a solid solution and nucleation of equiaxed grains.**

## ACKNOWLEDGMENT

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# RECLAIM SODIUM SILICATE BONDED SAND

By George C. Warneke

## ABSTRACT

**The objective of this project was to determine whether or not sodium silicate bonded sands could be reclaimed and, if so, what would be involved, and what could be expected as to repetitive dimensional accuracy of the sodium silicate bonded mold. A pneumatic scrubber and an aerated muller were used in the reclamation tests. A casting from green sand was compared for dimensional accuracy with a casting from sodium silicate bonded sand.**

## INTRODUCTION

The sodium silicate process has been in use for some time. To obtain the answers to two objectives which it was felt had never been thoroughly investigated, a project was initiated to find out whether or not sodium silicate bonded sands could be reclaimed, and if so what would be involved and what could be expected in repetitive dimensional accuracy of a sodium silicate bonded sand mold.

The sodium silicate process has had many pros and cons. Much publicity has been given the cost and savings factors of molds and cores free from any sag or distortion, and the freedom from use of driers, ovens and large storage areas, as well as the personnel to service them. One factor, and a basic and costly one, that it was felt had never been investigated was the basic core or mold sand used.

If this sand had to be discarded after each use, the use of sodium silicate as a bonding agent could become economically prohibitive, even though the process was of value in other areas.

## PROCEDURE

In order to produce castings from sodium silicate bonded sands at the lowest economic level, the sand necessarily must be reclaimable. The casting chosen to determine the merits and/or faults of a reclaimed sodium silicate bonded sand was the Steel Founders' Society of America standard test block. Figure 1 is a sketch of this test block casting.

The mold is shaped and gated to produce severe conditions against the sand interface. The casting is gated into the thin wing causing the metal to cover, uncover and re-cover the bottom of the thin wing area before running over the edge and subjecting itself to the side and bottom grooves. This casting was used to evaluate the relative erosion, penetration and burn-on conditions of the reclaimed sodium silicate bonded sand after each repetitive sand reclamation.

The first mix used to mold these S.F.S.A. test block castings contained 6 per cent sodium silicate and 2 per cent kaolin clay. Although this mix gave an excellent casting as to surface finish, with no penetration or burn-on on the bottom of the thin wing or in the bottom of side grooves, shake-out was extremely difficult. This sand with the high percentage of sodium silicate was shaken out in the form of large, hard chunks. Upon crushing these large chunks the sand grains were fractured making this mix with a high sodium silicate content unsatisfactory for reclamation, or from the standpoint of shake-out properties.

The next step was to lower the sodium silicate content, so that the shake-out properties would be improved and not create any difficulties, as well as to produce a sand which could easily be crushed, a necessary step between shake-out and reclamation. A figure of 4 per cent sodium silicate was chosen, as this amount, or slightly less, is used in many foundries for normal sodium silicate core and mold production.

The S.F.S.A. test block castings which resulted from this mix were not 100 per cent defect free as were the 6 per cent castings. However, these 4 per

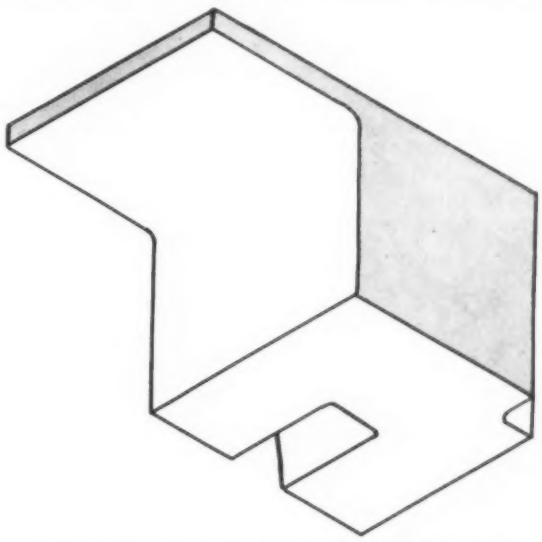

Fig. 1 — Sketch of test block casting used for this study.

G. C. WARNEKE is Foundry Engr., National Malleable & Steel Castings Co., Melrose Park Works, Melrose Park, Ill.

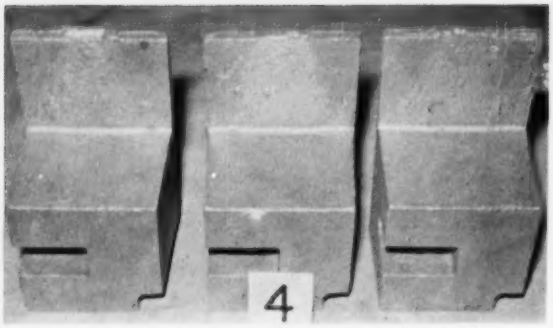


Fig. 2 — Casting made from new Ottawa sand having an AFS Grain Fineness Number of 48.41.

cent castings could easily be used as original sand castings, for comparison purposes, with castings made from the same sand after reclamation.

Figure 2 shows the castings made from new Ottawa sand having an AFS Grain Fineness Number of 48.4. The additives used were 4 per cent sodium silicate and 2 per cent kaolin clay. Note the erosion on the bottom of the thin wing, although the bottom and side grooves are free of defects. These were the standard castings against which test block castings, made with the same sand after its reclamation, were to be compared. These castings made from a mix with a 4 per cent sodium silicate content were easily shaken out, and the sand was readily crushed without grain fracture.

## RECLAMATION PROCESSES

The 4 per cent sodium silicate bonded sand was then divided into two equal parts and reclaimed by two different methods:

1) In a pneumatic scrubber.
2) In an aerated muller.

Reclamation by the pneumatic scrubber was done at the rate of 1000 lb/hr in a two-compartment unit. Six groups of castings were made; the original, and a group after each of the five reclamations.

The sodium silicate bonded sand used to make these castings was cured with carbon dioxide, the gas entering the mold through slotted vents in the pattern plate from a plenum chamber under the pattern plate. Before each re-use of the sand, it was tested for usable sodium silicate; none was found at any time. The casting to sand ratio was 1 to 3; perhaps with a higher ratio some sodium silicate may

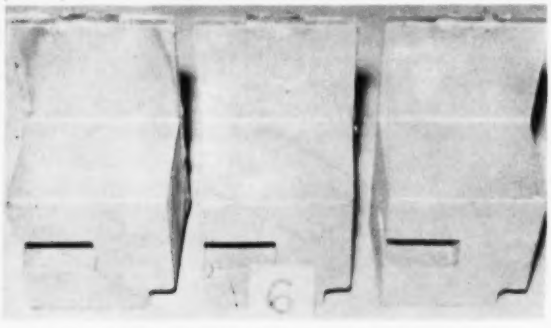


Fig. 4 — Castings made after second sand reclamation in the pneumatic scrubber.

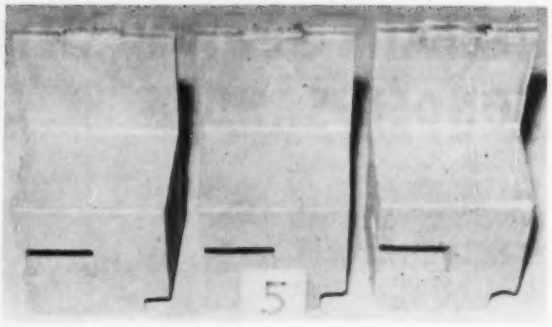


Fig. 3 — Castings made after the sand's first reclamation in the pneumatic scrubber.

be available for re-use. Twenty per cent new sand was added to each batch of reclaimed sand.

This was done to accomplish a two-fold purpose:

1) To make up the approximate 15 per cent loss shared between the reclaimer and the crusher, where 1/8-in. "peanuts" were screened from the sand after crushing.
2) To be able to vary the Grain Fineness Number of this 20 per cent addition, so when it was blended with the returned reclaimed sand the fineness number of the reclaimed sand could be kept in the range of the original new sand.

### Pneumatic Scrubber Reclamation

In Fig. 3 are castings made from the sand after its first reclamation in the pneumatic scrubber. As can be seen, the castings appear similar to the original new sand castings as to surface finish on the bottom of the thin wing, the same erosion condition in area and degree of severity and the absence of defects in the bottom and side grooves.

Figure 4 shows castings made from the sand after its second reclamation in the pneumatic scrubber. They are identical with original castings, and with castings made after the first reclamation.

In Fig. 5 are castings made after the sand's third reclamation. They are slightly improved over the original castings with regard to the erosion condition at the bottom of the thin wing. No explanation is offered as to why this situation occurred. The sand, as to grain fineness and distribution, was virtually the same as when it was used to make the original castings.

The foundry practice was duplicated as closely as

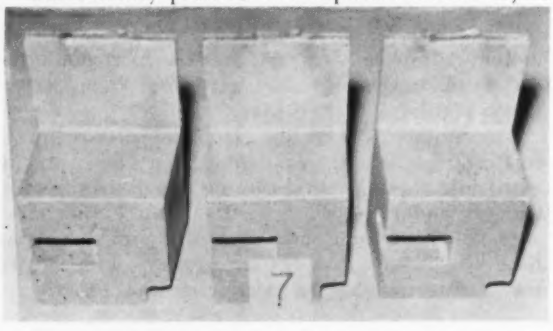


Fig. 5 — Casting made after third reclamation of sand in the pneumatic scrubber.

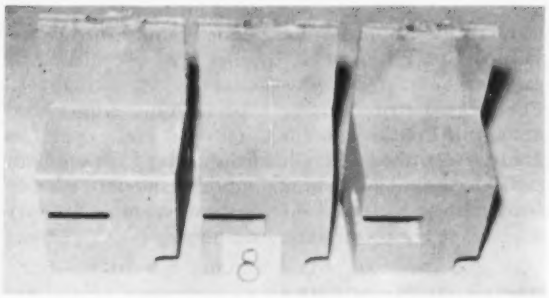


Fig. 6 — Castings made after fourth reclamation of sand in the pneumatic scrubber.

possible, as was the pouring practice. The metal temperature was the same as used in the original castings.

Figure 6 shows castings made from sand after the fourth reclamation. Again, these castings are similar to the original new sand castings, having the erosion condition on the bottom of the thin wing.

In Fig. 7 are castings made after the sand's fifth reclamation. Again, these castings are similar in appearance to the original new sand test block castings.

Conditions that were discernable in looking at the actual castings, and which could not be reproduced well on the photographic negatives, were the slight differences between the groups of castings even though they may be said to appear similar. In all cases, except one, a general improvement in surface conditions of a group of castings could be traced to that group of castings coming from a sand that had a slightly higher grain fineness number.

### Aerated Muller Reclamation

The second method of reclamation employed an aerated muller. This was done at the rate of 350-lb batches mulled and aerated for 20 min, and discharged through a cyclone. Again, six groups of S.F.S.A. test block castings were made—the original with new sand, and a group after each of the five reclamations of the sand.

These groups of castings were made simultaneously with groups of castings from sand reclaimed in the pneumatic scrubber, in order that molds made with sand after its first reclamation in the aerated muller, and molds made with sand after its first reclamation in the pneumatic scrubber, could be poured in the same heat.

This procedure was followed with the second, third, fourth and fifth reclamations by each method. The same foundry practice, bond additions, blending procedure and sand mulling practice was used as was used in the sand that was reclaimed by the pneumatic scrubber. This procedure was followed to minimize the many variables.

Figure 8 shows castings made with the sand after its first reclamation in the aerated muller. The surface appearance on the bottom of the thin wing is slightly better than that on the original new sand castings. This is attributed to the fact that this sand had a grain fineness number 7 points higher than that of the original sand. It is felt that this was caused by the negative pressure not being high enough in the muller, and to the many fines retained in the sand.

Fig. 7 — Castings made after fifth sand reclamation in the pneumatic scrubber.

In Fig. 9 are castings made with the sand after its second reclamation in the aerated muller. In appearance they are similar to the original new sand castings, having the slight erosion condition on the bottom of the thin wing.

Figure 10 shows castings made with the sand after its third reclamation. Notice the improved surface condition. These castings from reclaimed sand are mates to the castings from sand reclaimed in the pneumatic scrubber. As noted previously, even after extensive checking, no cause can be found for these castings having the improved surface after the third reclamation by either method.

Figure 11 shows castings made from the sand after its fourth reclamation. As can be seen, these castings have the same general surface conditions, with the slight erosion condition in the bottom of the thin wing and the absence of defects in the bottom and side grooves, as did the original new sand castings.

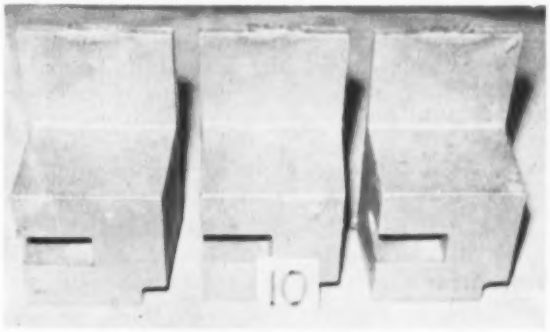


Fig. 8 — Casting made after the sand's first reclamation in the aerated muller.

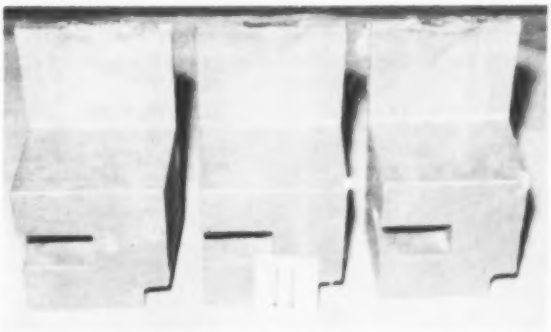


Fig. 9 — Castings made after second sand reclamation in the aerated muller.

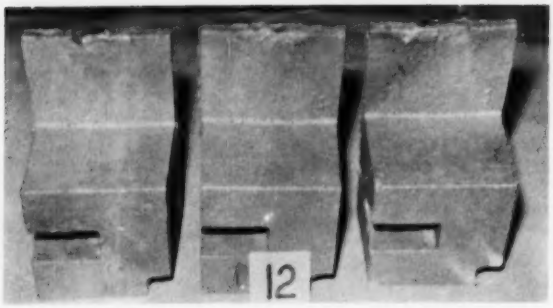


Fig. 10 — Castings made after third reclamation of sand in the aerated muller.

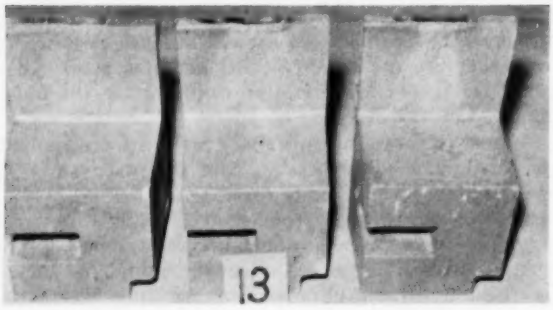


Fig. 11 — Castings made after fourth sand reclamation in the aerated muller.

In Fig. 12 are castings made from the sand after its fifth reclamation in the aerated muller. Again, the castings have a similar surface appearance on the bottom of the thin wing as did the original castings and castings made from sand after its second and fourth reclamations.

A similar situation existed with these castings as did with the others from sand reclaimed in the pneumatic scrubber, although the photographs have not detailed slight differences too closely. Actual examination of the groups of castings showed a correlation of slight differences in surface conditions following the grain fineness number of the sand used in the experiments. A finer sand gave a general surface finish improvement.

### Conclusions

Based on the results of this project, where the base Ottawa sand was reclaimed five times in an aerated muller and a pneumatic scrubber, and used to cast S.F.S.A. standard test blocks (used to compare the reclaimed sand with the original new sand), it appears that sodium silicate bonded sands can be reclaimed in an aerated muller or a pneumatic scrubber.

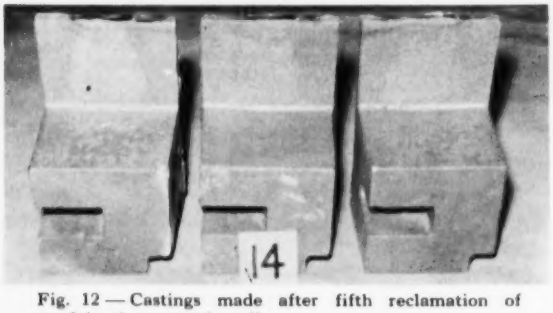


Fig. 12 — Castings made after fifth reclamation of sand in the aerated muller.

One thing that must be kept in mind with either method of reclamation is that the sand must be physically crushed after shake-out. The sand will not readily crumble as do most foundry sands after being passed through a sand tumbler and returned either to a storage hopper or a sand reclaimer.

## DIMENSIONAL ACCURACY

This section deals with the dimensional accuracy that can be obtained from a sand mold using a sodium silicate binder. By "dimensional accuracy" is meant repetitive dimensional accuracy from any size lot of repetitive productive castings.

Figure 13 shows the casting chosen to be examined dimensionally in six different places. It is a production casting normally cast in green sand.

Figure 14 is a schematic view of the casting which was used to compare the repetitive dimensional accuracy of sodium silicate bonded molds with that of the green sand molds. As can be seen, dimensions were taken at *A*, between a pair of vertical inside walls of two pockets and at *B*, (90 degrees to dimension *A*) between a pair of outside vertical walls. Dimension *C* is comparable to dimension *B* except that it is in the cope. Dimension *D* is the overall outside length of the mold.

Dimension *E* is the depth of the drag from the parting line to the lowest point, and dimension *F* is an overall dimension of cope and drag total height. The dimensions involved cover all areas where the castings may be distorted either in molding or pouring operations. A total of 84 of these castings was made in sand molds bonded with sodium silicate. A similar number of regular production green sand castings were selected at random to be compared with these castings from sodium silicate bonded sand molds.

Dimension *A* on castings from sodium silicate bonded sand molds averaged 7.6 in., all dimensions being taken with a vernier caliper. When all 84 dimensional readings were subjected to statistical analysis, the average variation which could be expected 95 per cent of the time was a tolerance of $\pm 0.016$ in. of the average dimension. This was established by analyzing the data sheets, and taking the average tol-

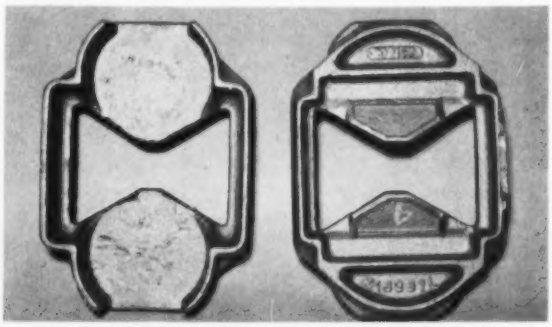

Fig. 13 — Casting chosen to the examined dimensionally in six different places. It is a normal production casting usually cast in green sand.

erance plus or minus twice the standard deviation, being 0.008 in.

Dimension *A* on castings made by conventional green sand molding methods had an average of 7.615 in. When all 84 readings of dimension *A* of the green sand molded castings were subjected to statistical analysis, the average variation which could be expected 95 per cent of the time was a tolerance of ±0.028 in. of the average dimension.

This again was established by analyzing the data sheets and taking the average tolerance plus or minus twice the standard deviation of green sand, being 0.014 in. Therefore, the use of a sodium silicate bonded sand in preference to conventional green sand would permit the molding of this 7⅝ in. dimension with the range of variation cut approximately in half.

Dimension *B*, at 90 degrees to dimension *A*, on castings from sodium silicate bonded molds averaged 7.901 in. Again, when all 84 of these dimensional readings were subjected to statistical analysis, the average variation to be expected 95 per cent of the time was a tolerance of ±0.016 in. of the average dimension. This same dimension on the green sand castings averaged 7.874 in. The statistical analysis showed the average variation to be expected 95 per cent of the time was a tolerance of ±0.028 in.

As in the previous case, molding with a sodium silicate bonding agent would permit holding as-cast tolerances only approximately half as great as found with conventional green sand molding.

Dimension *C* is comparable to dimension *B*, except that it is in the cope. In castings from sodium silicate molds this dimension averaged 7.984 in. When the 84 readings taken on all castings at this location were statistically analyzed, the average variation to be expected 95 per cent of the time was ±0.038 in. This is not in relationship to a previous dimension of approximately the same magnitude although in a different location.

Also, there is no correlation between this and the dimension taken in the same location on green sand castings where the average dimension was 7.964 in., with a statistically analyzed tolerance range of 0.028 in. No explanation is offered for the increased tolerance range at this location on the sodium silicate bonded sand castings.

Dimension *D* has an outside length dimension average of 12.145 in. on castings from sodium silicate bonded sand. The statistical analysis of the 84 dimensions taken at this location showed the average variation to be expected 95 per cent of the time was ± 0.026 in. Comparing the green sand castings at this location, the average dimension was 12.180 in. and

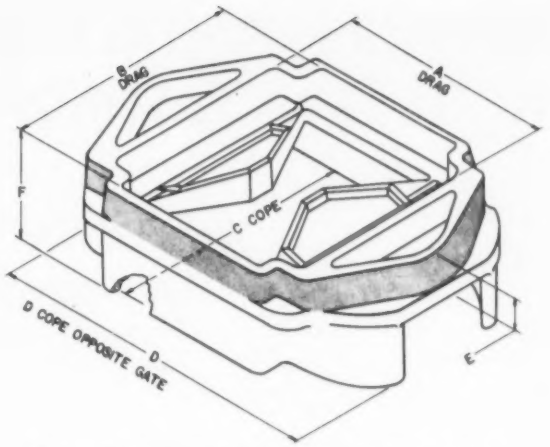


Fig. 14 — Schematic view of casting shown in Fig. 13.

the tolerance to be expected 95 per cent of the time was ±0.050 in.

As in the first two cases, the use of a sodium silicate bonded sand gave dimensional variations only half as great.

Dimension *E* is a depth dimension of the drag half of the casting from the parting line to the bottom of the mold, and had an average dimension on sodium silicate bonded sand castings of 1.362 in. When the readings from 84 castings in this area were analyzed the average variation to be expected was ±0.028 in. Comparing this with the same dimension on green sand castings, it averaged 1.367 in. and had a tolerance range of ±0.032 in.

Although not as great as in previous cases, the sodium silicate bonded mold gave smaller tolerance variations.

The last dimension, dimension *F*, although averaging 3.318 in. on sodium silicate bonded sand castings could not be properly analyzed due to a skewed distribution. The molds were all weighted uniformly and were subjected to different pouring pressures, which caused no serious horizontal mold wall deviations, but were affected vertically by the static pressure of the metal being poured. Therefore, no statistical analysis of a standard deviation could be properly established. The same situation occurred with the green sand molds where the average dimension of 84 castings was 3.318 in.

## Conclusions

In the casting just analyzed, allowing for the one exception, a sand mold bonded with sodium silicate will provide greater dimensional stability, and a smaller as-cast tolerance range, than will the conventional green sand practice.

# MOTTLING IN HEAVY SECTION WHITE IRON CASTINGS

## *first progress report on an investigation sponsored by AFS Malleable Division*

By C. R. Loper, Jr. and R. W. Heine


### ABSTRACT

**There is an increasing demand on malleable iron foundries to produce castings of a larger section size. However, the problems of producing the casting without mottling and with adequate annealability arise.**

**To seek a solution to these problems a research project is being sponsored by the American Foundrymen's Society Malleable Div. at the University of Wisconsin. The project is aimed at producing heavy section castings from an iron of such composition and/or melting practice that mottling or primary graphitization will not occur during the freezing of the casting. However, the iron must have sufficient graphitizing tendency in the solid state so that it may be malleabilized by a commercially feasible heat treatment. This paper is the first progress report emanating from this project.**


### LITERATURE SURVEY

In general, articles published in the literature[1-17] which have a bearing on the problem state that carbon and silicon exert a dominating effect on mottling tendency in a given section size. Lowering the carbon and silicon to sufficiently small percentages will prevent mottling and cause a white fracture. Slightly higher percentages of carbon and silicon may or may not cause mottling, depending on section size and melting practices. At still higher percentages of carbon and silicon mottling will occur consistently.

This relationship between chemical composition and mottling tendency can be established by correlating the appearance of mottling with certain limiting maximum carbon and silicon contents for a given casting section size and a given melting practice. Among the criteria for combination of carbon, silicon and section size which have been suggested in the literature are:

a) $\%C + 2.85 \times \log \%Si = 2.703 - 1.06 \log D$;[2] where $D$ = section diameter for bars in in. For a 2.0 in. diameter bar, $\%C + 2.85 \log \%Si = 2.703 - 1.6 \times 0.302 = 2.22$.

b) $\%C + 2.85 \times \log \%Si = b$;[3] where $b$ is a constant which depends on section size. For irons produced in three foundries, a statistical study revealed that elimination of mottling in a 2.0 in. diameter section occurs when b = 2.55.

c) $4.25 \times \%C + 1.82 \times \%Si = 12.20$ or less; to eliminate mottling in a 2.0 in. diameter bar.[4]

d) $\%C + \%Si = k$; this is an arbitrary relation where a limiting value of $k$ is assigned by a particular foundry based on their experience with a test bar. For a 2.0 in. diameter bar, constant $k$ usually is in the range of 3.6 to 4.0.

e) $4.10 \times \log \%C + \log \%Si = 1.602$;[1] where the data from formulas (b) and (c) are also found to fit in the normal carbon and silicon percentage range in malleable iron.

In the above relationships (a) through (e), the combination of carbon and silicon percentage on the left side of the equation must be below the value expressed on the right side of the equation, in order to obtain a white cast iron regardless of melting variables. Three of these formulas are plotted in Fig. 1, along with the eutectic carbon and silicon percentage, $\%C + 1/3\ \%Si = 4.30$, and the maximum solubility of carbon in $\gamma$ iron alloyed with silicon ($\%C + 1/6 \times \%Si = 2.0$).

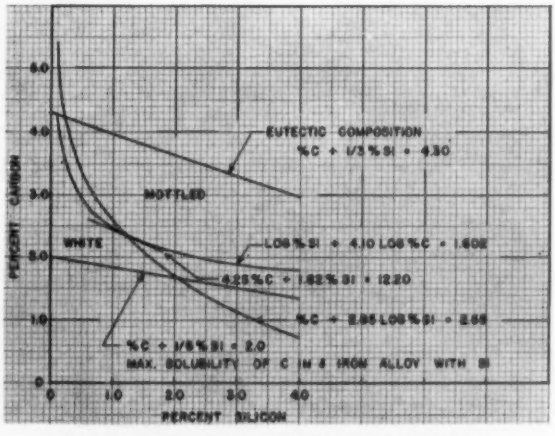


**Fig. 1 — Comparison of three criteria of mottling, in a 2.0 in. diameter bar with eutectic carbon and silicon concentrations, and with maximum solubility of carbon in austenite as affected by per cent silicon.**

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Theoretically, the correct equation should have a curve approaching the eutectic carbon content (4.30 per cent), or slightly above, as silicon approaches zero, since it has been observed that hypereutectic irons will always cast with structures containing primary graphite even in sections under 1/8-in. diameter quenched in water. The correct equation should also have a curve approaching or slightly below the maximum solubility of carbon in austenite as silicon content increases. This is necessary since mottling is regarded as the precipitation of graphite during freezing of the eutectic. No eutectic will be formed at compositions much below those of the solubility level of carbon in silicon alloyed iron.

A comparison of the curves (b) $\%C + 2.85 \times \log \%Si = 2.55$, (c) $4.25 \times \%C + 1.82 \times \%Si = 12.20$ and (e) $4.10 \times \log \%C + \log \%Si = 1.602$, is presented in Fig. 1. Equation (b) appears to cross the curve of maximum solubility of carbon in austenite at too low a silicon percentage to be valid. Since the data[3] from which curve (b) is taken also fits equations (c) and (e), it appears that equation (e) is the best interpretation of available data on the limits of C and Si for mottling in a 2.0 in. diameter test bar.

A better curve would be one where the equation is asymptotic both to the zero per cent silicon line near the eutectic composition and the maximum solubility of carbon in austenite curve.

The preceding discussion concerns comparisons in the literature regarding limiting carbon and silicon contents for mottling in a 2.0 in. diameter section. A base curve which is asymptotic to the zero per cent silicon ordinate, and the line indicating maximum solubility of C in $\gamma$ iron ($C + 1/6 \times \%$ Si) is indicated as theoretically correct for the 2.0 in. diameter section. A similar base curve of limiting carbon and silicon contents should exist for heavier sections such as the 4 x 4 x 8 in. block casting selected as a test bar for mottling in this project.

The first phase of the project consisted of determining this base curve of carbon and silicon for producing a white fracture in a 4 x 4 x 8 in. block casting. The effects of other variables, for example bismuth, can then be related to this base curve.

## EXPERIMENTAL PROCEDURE

The mottling test casting selected by the committee was a block 4 x 4 x 8 in. long made in a green sand mold, and fed by a 9 x 4¾ in. diameter riser. The drag side of the pattern is shown in Fig. 2. A thermocouple protected by a fused silica tube was inserted into the center of the 4 x 4 x 8 in. block from the top, in order to obtain cooling curves on the casting. Thirty to 35 min were required after pouring for complete solidification of the 4 x 4 x 8 in. block. Mottling data of this casting were obtained from the fracture between the riser and the 4 x 4 x 8 in. block, and from fracture at the center of the block.

The fracture was called white only if it showed no evidence whatever of mottling. It was called lightly mottled when about 6 to 12 mottle specks showed on the 4 x 4 in. section. Heavily mottled is the term used to describe a fracture about 50 per cent white and 50 per cent gray. Mottled describes a fracture which is about 75 per cent white.

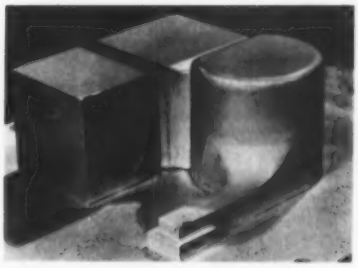

Fig. 2 — Drag view of the pattern of the 4 x 4 x 8 in. casting from which mottling data were obtained.

TABLE 1 — CHEMICAL ANALYSIS AND SURFACE AREA OF CHARGE MATERIALS

| Material | Composition, % | | | | | Average Surface Area, in.²/lb |
|---|---|---|---|---|---|---|
| | C | Si | Mn | S | P | |
| Pig Iron | 4.20 | 1.62 | 0.80 | 0.043 | 0.13 | 8.0 |
| Sprue | 2.36 | 1.18 | 0.31 | 0.090 | — | 17.0 |
| Steel | 0.24 | 0.09 | 0.66 | 0.04 | — | 22.4 |

All heats were melted in a high frequency induction furnace under a controlled atmosphere. With the exception of a few high carbon, low silicon heats, this atmosphere consisted of 21 per cent carbon dioxide and 79 per cent nitrogen. The $CO_2$ - $N_2$ atmosphere was selected since it represents the most oxidizing melting condition without free oxygen, or the case where perfect combustion of carbon takes place.

High carbon, low silicon heats 22, 25, 30 and 31 were melted in a 35 per cent carbon monoxide, 65 per cent nitrogen atmosphere because of their tendency to boil when melted under the 21 per cent $CO_2$-79 per cent $N_2$ atmosphere. The 35 per cent carbon monoxide atmosphere represents the case where a solid fuel is completely burned to CO with no excess $O_2$.

Table 1 presents the chemical analysis and approximate surface area of the charge ingredients. With a few exceptions, 50 per cent sprue was used in all charges. The chemical composition was adjusted through proper proportioning of pig iron, sprue, steel and 75 per cent silicon ferro-silicon or graphite obtained from crushed electrodes. The pig iron was sawed into pieces 4 to 8 in. long for convenience in charging. The steel consisted of scrap nuts and bolts. All charge ingredients were thoroughly cleaned of adhering dirt and scale.

### Charging Procedure

Charging procedure was as follows:

1) The pig iron was placed in the bottom of the furnace.
2) Ferro-silicon, if required, was placed on top of the pig.
3) Sprue was then placed on top of the pig.
4) As melting progressed steel was added.
5) Any graphite required, was added to the charge after the melt reached a temperature of 2570-2800 F, and was cleaned of slag. At this temperature the graphite entered readily into solution.

Melt down time for all heats was about 65-70 min. The bath was brought up to 2800 F in a total of 80-

TABLE 2 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEAT POURED — NO ADDITION MADE

| Heat No. | Chemical Analysis, %[1] C | Si | Fracture Results[2] 4x4x8 in. casting | 1⅞ in. D. bar |
|---|---|---|---|---|
| 1 | 2.50* | 1.09* | G | M |
| 2 | 2.50* | 1.32* | G | M |
| 8 | 2.39* | 1.40* | G | M |
| 11 | 2.44* | 1.05* | M | W |
| 12 | 2.34* | 1.05* | M | LM |
| 13 | 2.20* | 1.41* | HM | M |
| 14 | 2.12* | 1.21* | M | W |
| 15 | 1.85 | 0.86 | W | W |
| 16 | 2.34* | 0.95* | M | W |
| 17 | 2.10* | 0.82* | LM | W |
| 18 | 2.10 | 0.87 | M | W |
| 19 | 1.90* | 1.12* | LM | W |
| 20 | 2.00 | 1.15 | M | W |
| 21 | 1.85* | 1.41* | LM | W |
| 22 | 3.00 | 0.40 | M | W |
| 24 | 1.50 | 4.00 | G | HM |
| 25 | 3.03* | 0.25* | LM | W |
| 26 | 1.13 | 4.00 | W | W |
| 27 | 1.32* | 3.54* | W | W |
| 28 | 1.63 | 2.00 | HM | — |
| 29 | 1.46* | 3.94* | HM | HM |
| 30 | 2.60* | 0.25* | W | — |
| 31 | 2.80 | 0.31 | W | W |
| 54 | 2.11 | 1.65 | G | LM |
| 55 | 2.11 | 1.65 | G | LM |

1. Estimated chemical analyses, unless marked with an asterisk for which actual chemical analyses were obtained.
2. G = gray fracture; HM = heavily mottled fracture, almost gray; M = mottled fracture; LM = lightly mottled fracture; W = 100 per cent white fracture.

90 min from the start of the heat. The heat was then held at 2800 F for 60 min. The furnace was turned off and the melt allowed to cool. In about 3 min the bath dropped to a temperature of 2750 F, and in another 2 min the bath temperature dropped to 2700 F.

Those heats to which no additions were made were poured at 2700 F. In the case of heats having a bismuth addition, the bismuth was added at 2750 F, and the heat poured at 2700 F. The bismuth added was wrapped in a sheet of mild steel, wired to a fused silica rod and subsequently immersed in the bath. As a result of the melting practice followed, no oxidation losses of silicon occurred from charge to final analysis. Total decarbonization amounted to about 0.30 per cent for each heat.

The final analysis is listed in Table 2. Table 2 lists actual chemical compositions for 15 heats and estimated compositions for 10 heats. Only the significant heats were analyzed. However, past experience has shown that estimated analyses are always correct within a few points of carbon and silicon.

## RESULTS

The effect of carbon and silicon percentages on the fracture of the 4 x 4 x 8 in. casting is listed on Table 2, and shown graphically in Fig. 3. Figure 3 also shows the line representing the maximum solubility of carbon in austenite. The curve representing the maximum carbon and silicon contents which will produce a white fracture in the 4 x 4 x 8 in. casting is seen to be asymptotic to the 0 per cent silicon line and the curve of maximum solubility of carbon in austenite.

Increasing the carbon or silicon percentage from this base line in Fig. 3, in the region less than 2.50 per cent silicon, will result in a slightly mottled fracture. Further increase will result in heavier mottle and finally a fully gray fracture. The base curve for carbon and silicon limits for gray fractures is also shown in Fig. 3. Carbon and silicon contents in excess of those on this base curve will produce a gray fracture in the 4 x 4 x 8 in. casting.

Silicon contents of greater than 2.50 per cent produce an interesting result. From Fig. 3 it may be noticed that above 2.50 per cent silicon the base curves for white and gray fractures appear to be coincident. This means that a small increase in carbon content changes the fracture from fully white to completely gray.

## BISMUTH EFFECT

In order to produce heavy section malleable castings the base curve on Fig. 3 for white fractures must be raised to higher silicon and carbon contents. This is necessary in order to obtain sufficient graphitizing tendency on annealing. Ladle additions of bismuth have been used for this purpose in malleable foundries, as reported in references.[5,15] The effect of bismuth additions to the metal may be seen in Fig. 4, the data for Fig. 4 being presented in Table 3.

This curve represents the shift in base line brought

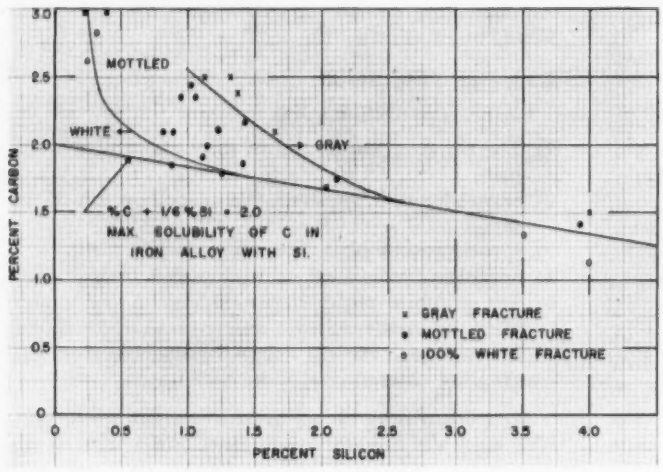


Fig. 3 — Carbon and silicon content effect on the fracture obtained in the 4 x 4 x 8 in. casting showing the maximum carbon and silicon percentages which will yield a fully white fracture, and the minimum carbon and silicon percentages which will yield a completely gray fracture.

about by the addition of 0.01 per cent bismuth, according to the procedure described earlier. The effect of bismuth is seen to be much more pronounced at lower silicon contents than at higher silicon contents, according to Fig. 4. In fact, it appears that beyond about 2.40 per cent silicon, little or no effect on the fracture will be obtained from 0.01 per cent bismuth addition.

Fracture results on casting of an analysis just to the right of the curve for 0.01 per cent added bismuth appear to be identical to those just to the right of the base line curve when no bismuth is added. The effect of 0.01 per cent bismuth in the area of the shifted base line curve, presented in Fig. 4, is to change the fracture from very heavily mottled to fully white, or from completely gray to very lightly mottled. This may be noted by comparison of Figs. 3 and 4.

The effect of bismuth additions larger than 0.01 per cent is shown in Fig. 5. In the compositions studied, bismuth in amounts of 0.02 to 0.10 per cent produced no greater effect than that obtained from 0.01 per cent bismuth. Fracture results from these increased percentages of bismuth were similar to those of 0.01 per cent bismuth additions at corresponding carbon and silicon contents.

## TEMPERATURE OF BISMUTH ADDITION EFFECT

The effect of adding bismuth at 2600 F rather than 2750 F was studied with results reported in Table 4. Bismuth additions of 0.01 per cent at 2600 F resulted in gray fracture in heats 67, 68 and 70, whereas a lightly mottled fracture would be expected in heat 67 and a heavily mottled fracture would be expected in heats 68 and 70. Heat 67 had an analysis of 2.30 per cent C and 1.65 per cent Si, and would normally show a lightly mottled fracture from the addition of 0.01 per cent bismuth at 2750 F (Fig. 3).

However, it had a gray fracture when the bismuth was added at 2600 F. Heats 68 and 70 had an analysis of 2.58 per cent C and 1.65 per cent Si, and would normally show a heavily mottled fracture from the addition of 0.01 per cent Bi at 2750 F. However, it had a gray fracture when the bismuth was added at 2600 F. Thus, it is seen that the temperature of bismuth addition is exceedingly important in obtaining its full affect on raising carbon and silicon limits for mottling.

## WATER VAPOR EFFECT

It has been previously reported that water vapor in the furnace atmosphere raised the base curve for a white fracture in a 2.0 in. diameter bar.[2] The effect of water vapor on the base line for white fractures in the 4 x 4 x 8 in. test casting is presented in the data in Table 4. Water vapor in the amount of 12 grains cu ft of gas in a $CO_2 \cdot N_2$ atmosphere, heat No. 43, produced a lightly mottled fracture in an analysis of 2.10 per cent C, 1.63 per cent Si identical with that to be expected from 0.01 per cent Bi addition, as shown in Fig. 4.

Heat No. 47, containing 2.14 per cent C and 1.40 per cent Si, to which 25 grains water vapor/cu ft of

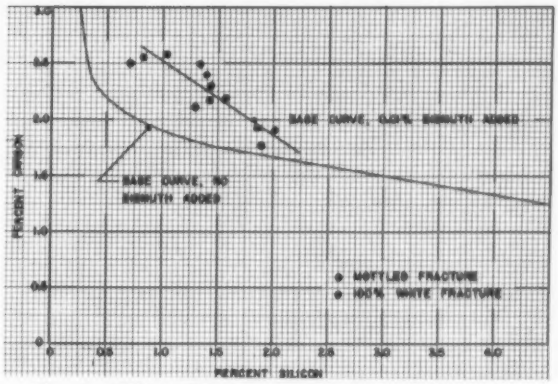


Fig. 4 — Effect of 0.01 per cent Bismuth added on the base curve of maximum carbon and silicon percentages which will yield a fully white fracture in the 4 x 4 x 8 in. casting.

TABLE 3 — CHEMICAL ANALYSIS AND FRACTURE RESULTS OF HEAT POURED, 0.01 PER CENT BISMUTH ADDED

| Heat No. | Chemical Analysis, %[1] C | Si | Fracture Results[2] 4x4x8 in. casting | 1⅞ in. D. bar |
|---|---|---|---|---|
| 3 | 2.50* | 1.33* | M | W |
| 6 | 2.42* | 1.39* | M | W |
| 9 | 2.34* | 1.42* | M | M |
| 33 | 1.77* | 2.00* | M | M |
| 34 | 2.18* | 1.41* | W | W |
| 35 | 2.68* | 1.03* | M | W |
| 36 | 1.77* | 1.80* | W | W |
| 37 | 2.11 | 1.30 | W | W |
| 38 | 2.50 | 0.70 | W | W |
| 39 | 1.77 | 1.90 | W | W |
| 40 | 2.18* | 1.57* | LM | W |
| 41 | 2.50* | 0.85* | W | W |

1. Estimated chemical analyses unless marked with an asterisk for which actual chemical analyses were obtained.
2. M = mottled fracture; LM = lightly mottled fracture; W = 100 per cent white fracture.

TABLE 4 — CHEMICAL ANALYSIS AND FRACTURES, VARIOUS ADDITIONS

| Heat No. | Chemical Analysis, %[1] C | Si | Addition | Fracture Results[2] 4x4x8 in. casting | 1⅞ in D. bar |
|---|---|---|---|---|---|
| 4 | 2.40* | 1.30* | 0.02 Bi | M | W |
| 5 | 2.36* | 1.28* | 0.05 Bi | M | W |
| 7 | 2.40* | 1.49* | 0.10 Bi | M | — |
| 10 | 2.41* | 1.41* | 0.10 Bi | M | W |
| 42 | 2.11 | 1.65 | 0.05 Bi | LM | W |
| 43 | 2.10* | 1.63* | 12 gm $H_2O$/cu ft gas | LM | W |
| 46 | 2.19* | 1.64* | 12 gm $H_2O$/cu ft gas plus 0.01% Bi | LM | LM |
| 47 | 2.14* | 1.40* | 25 gm $H_2O$/cu ft gas | W | W |
| 52 | 2.11 | 1.65 | 0.05 Bi | LM | W |
| 60 | 2.11 | 1.65 | 0.01 $Bi_3$ | W | — |
| 67 | 2.30 | 1.65 | 0.01 $Bi_3$ | G | G |
| 68 | 2.58 | 1.65 | 0.05 Bi | G | G |
| 69 | 2.58 | 1.65 | 0.05 $Bi_3$ | HM | — |
| 70 | 2.58 | 1.65 | 0.05 Bi | G | — |

1. Estimated chemical analyses unless marked with an asterisk for which actual chemical analyses were obtained.
2. G = gray fracture; HM = heavily mottled fracture, almost gray; M = mottled fracture; LM = lightly mottled fracture; W = 100 per cent white fracture.
3. Bismuth additions made and castings poured at 2600 F compared to normal procedure of adding bismuth and pouring at 2750 F.

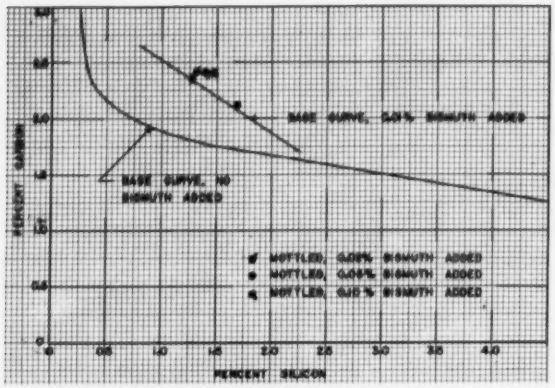
BASE CURVE, 0.01% BISMUTH ADDED
BASE CURVE, NO BISMUTH ADDED
MOTTLED, 0.01% BISMUTH ADDED
MOTTLED, 0.05% BISMUTH ADDED
MOTTLED, 0.10% BISMUTH ADDED
PERCENT SILICON

**Fig. 5 — Increased Bismuth additions effect on the base curve of maximum carbon and silicon percentages with 0.01 per cent Bismuth added, which will yield a fully white fracture in the 4 x 8 x 8 in. casting.**

gas in a $CO_2$ - $N_2$ atmosphere were added, produced a white fracture identical with that to be expected from 0.01 per cent Bi additions, shown in Fig. 4. Addition of 12 grains water vapor/cu ft gas in a $CO_2$ - $N_2$ atmosphere and 0.01 per cent bismuth to heat No. 46 of 2.19 per cent C, 1.64 per cent Si, produced a lightly mottled fracture identical with that obtained from water vapor alone or 0.01 per cent bismuth alone.

Therefore, it would appear, that similar results can be obtained from a controlled amount of water vapor in the furnace atmosphere, as can be obtained from the use of bismuth additions in so far as mottling is concerned. Water vapor, however, has been proved to interfere with second stage graphitization.[1]

## SUMMARY

Base line curves representing the maximum carbon and silicon content which will produce a white fracture in the 4 x 4 x 8 in. casting, and the minimum carbon and silicon content which will produce a gray fracture in the 4 x 4 x 8 in. casting have been presented in Fig. 3.

The effect of bismuth additions on the limiting carbon and silicon contents for white fracture in the 4 x 4 x 8 in. test casting has been shown in Fig. 4. Percentages of bismuth additions over 0.01 per cent have been shown to be of no value in reducing mottling in the 4 x 4 x 8 in. test casting insofar as obtaining a white fracture is concerned. Too low a temperature of addition (2600 F) reduces the effectiveness of the bismuth additions. Water vapor has been shown to be as effective as bismuth in raising carbon and silicon limits for mottling, according to the melting practices followed in this research.

Future studies on the casting of heavy section malleable will be aimed at ladle additions and/or melting practices that will raise the carbon and silicon limits for mottling above the base line curves presented in this report.

This paper is the first annual progress report of this project. As such, it should be recognized that the various graphs and conclusions stated, represent the best analyses of the data obtained thus far and they may be modified if future work so indicates.

## ACKNOWLEDGMENTS

The authors wish to express their thanks to the following persons who assisted on this project:

1) The members of the AFS Malleable Div. Research Committee for their efforts in guiding this project: C. F. Joseph, *Chairman;* W. D. McMillan, *Vice-chairman;* H. Bornstein; J. H. Lansing; S. C. Massari, *AFS Technical Director;* R. V. Osborne; R. Schneidewind; R. P. Schauss; M. Tilley; P. F. Ulmer; and E. Welander.
2) W. R. Marshall, *Associate Director,* Engineering Experiment Station; and P. C. Rosenthal, *Chairman,* Department of Mining and Metallurgy, for their administrative assistance.

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# news and views

■ Free listing forms for the AFS Buyers Directory must be received at the offices of the American Foundrymen's Society by **Monday, June 15,** according to a final warning issued by Curtis Fuller, directory manager.

"We have sent every supplier on our records three complete mailings explaining the purpose of the Directory," Fuller explained. "A few of them have not yet returned the listing forms enclosed and we want to remind these companies that our absolute deadline is June 15.

"Any company missing this target date will not have another chance to be listed for two years."

The first AFS Buyers Directory will be published Sept. 15 and will be distributed free of charge to every foundry superintendent in the United States and Canada. Multiple copies will be distributed in larger foundries.

The Directory will be a hard-covered book of 300 to 400 pages, size 8-1/2 x 11-1/2 in. It will list all known suppliers and all their equipment, products, supplies and services, classified and cross-indexed under more than 1000 specialized headings.

There will also be two complete trade name indexes, a listing of district sales offices and local distributors, and a considerable amount of information on all the associations and technical societies in the metalcasting industry.

This is the only Directory that has ever attempted to cover all suppliers, products, services and trade names of the foundry industry.

"We want to list everyone possible in the Directory — not only because listing will be extremely valuable to suppliers but because maximum completeness will make the Directory most useful to foundrymen," Fuller explained.

"We are forced to close the free listings sections on June 15 because each section is completely dependent upon each other section; and once the printer starts to set type for the Directory, every additional company name or product listing could only be handled as an expensive printer's alteration."

"Then, too, there's always the extra time necessary to put hard covers on approximately 12,500 books. We've had to put regular book covers on the Directory because of the rugged use we expect it will receive."

The American Foundrymen's Society has been developing the AFS Buyers Directory for more than a year and a half, after a survey of key foundry executives showed the need for such a compilation. Hitherto foundries have had to depend on general purchasing directories which are not specialized enough to serve foundry purchasing needs.

Most foundries had to maintain extensive filing systems which rapidly became obsolete, were bound to be incomplete and had no cross-indexing arrangements. The AFS Directory will not only be cross-indexed but will be vastly more complete as far as sources of supply are concerned.

A further advantage of the Directory will be listings of local and regional sales offices, representatives, warehouses and so on, listed alphabetically by state under the name of the parent company. Many foundries specifically requested that such listings be included in the Directory.

Advertisers in the Directory will also provide product information in a convenient form which will be cross-indexed to company and page number of ad.

Advertising deadline for the Directory has been set as July 1. The staff is able to accept advertising plates for a longer time than editorial copy because only full page ads are permitted and can be handled as independent units.

"We are encouraging advertisers to provide catalog-type copy for their ads," Fuller explained. "We expect this book to be consulted daily so it won't be as necessary for ads to attract attention as much as to give maximum information and descriptions of products. Ads will be read and consulted as a source of valuable information which the foundry superintendent or other purchasing executive will refer to and study just as if he were looking up a fact in the encyclopedia or dictionary. Our goal in developing this Directory is to make it of maximum value to the purchasing function in foundries."

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# Penn State Conference, June 25-27, Has Simultaneous Sessions and Sand School

■ Simultaneous gray iron, malleable iron, steel and non-ferrous sessions will be conducted Thursday afternoon, Friday morning and Friday afternoon at the three-day 2d Biennial Penn State Foundry Conference. Sand schools will be held Friday afternoon and Saturday morning.

The conference will be held June 25-27 at Pennsylvania State University, University Park, Pa., in cooperation with the university.

E. J. Biller, Vulcan Mold & Iron Co., Latrobe, Pa., is conference chairman. T. E. Eagan, Cooper-Bessemer Corp., Grove City, Pa., and H. C. Erskine, Aluminum Co. of America, Pittsburgh, Pa., are program co-chairmen.

Aside from the technical program, Thursday's activities include both a luncheon and an evening picnic and mixer. A banquet will be held Friday night.

Activities have been planned for ladies consisting of campus and area tours, exhibits and bridge. Ladies are also invited to the luncheon, picnic and banquet.

Sponsors of the conference are the Central New York, Chesapeake, Eastern New York, Metropolitan, Northwestern Pennsylvania, Ontario, Philadelphia, Pittsburgh, Rochester and Western New York AFS Chapters with the Foundry Educational Foundation, Foundry Equipment Manufacturers' Association, Conestoga Foundrymen's Association, Lehigh Valley Foundrymen's Association and Reading Foundrymen's Association.

The tentative program:

## THURSDAY, JUNE 25

### (Morning Session)

8:00 am Registration, lobby, Hetzel Union Building.

12:00 noon Luncheon, ballroom, Hetzel Union Building.
Toastmaster: C. W. Mooney, Olney Foundry, Link-Belt Co., Philadelphia.
Speaker: Eric A. Walker, president, Pennsylvania State University.

### (Afternoon Sessions)

**GRAY IRON**

Chairman: J. Douglas James, Urick Foundry Co., Erie, Pa.

1:30 pm *Some Factors for More Profitable Foundry Operation;* M. J. Kellner, Westinghouse Electric Corp., East Pittsburgh, Pa.

2:30 pm *Economical Founding of Ductile Iron Castings;* C. W. Gilchrist, Cooper-Bessemer Corp., Mt. Vernon, Ohio.

4:00 pm *Gating of Gray Iron Castings;* John F. Wallace, Case Institute of Technology, Cleveland.

**MALLEABLE IRON**

Chairman: David Tamor, American Chain & Cable Co., Reading, Pa.

1:30 pm *Oxygen in the Malleable Foundry;* John B. LaPota, Chemtron Corp., Chicago.

3:00 pm *Elevated Temperature Properties of Malleable Iron;* Lauriston C. Marshall, Link-Belt Co., Indianapolis.

**NON-FERROUS**

Chairman: S. A. Kundrat, James H. Matthews Co., Pittsburgh, Pa.

1:30 pm *Looking Ahead in the Non-Ferrous Foundry Industry;* A. R. Barbour, Roessing Bronze Co., Pittsburgh, Pa.

3:00 pm *Preventing Casting Defects;* Ray Cochran, R. Lavin & Sons Co., Chicago.

4:00 pm *Which Core Process in the Non-Ferrous Foundry;* Charles E. Coulter, Archer-Daniels-Midland Co., Cleveland.

**STEEL**

Chairman: R. W. Zillmann, Pittsburgh Steel Foundry Co., Pittsburgh, Pa.

1:30 pm *Occurrence, Production and Uses of Quality Silica;* L. G. Burwinkel, Jr., Pennsylvania Glass Sand Corp., Pittsburgh, Pa.

2:15 pm *Sand Segregation;* W. D. Chadwick, Manley Sand Co., Rockton, Ill.

3:30 pm *Cold Curing Type Binders;* Frank H. Dettore, G. E. Smith, Inc., Pittsburgh, Pa.

4:15 pm *Moldable Exothermic Materials;* John E. Gothridge, Foundry Services, Inc., Columbus, Ohio.

6:00 pm Picnic and Mixer, Penn's Cave.

## FRIDAY, JUNE 26

### (Morning Sessions)

**GRAY IRON**

Chairman: T. E. Eagan, Cooper-Bessemer Corp., Grove City, Pa.

9:30 am *Cupola Refractories;* T. E. Barlow, Eastern Clay Dept., International Minerals & Chemical Corp., Skokie, Ill.

11:00 am *Use of Alloys in Gray Iron Melting;* R. A. Clark, Union Carbide Metals Corp. Div., Union Carbide Corp., Cleveland.

**MALLEABLE IRON**

Chairman: Richard Zinn, American Chain & Cable Co., York, Pa.

9:30 pm *Pearlitic Malleable as an Engineering Material;* Carl F. Joseph, Central Foundry Div., GMC, Saginaw, Mich.

10:30 pm *Malleable Gating and Design;* Richard E. Rosien, Eastern Malleable Iron Co., Wilmington, Dela.

**NON-FERROUS**

Chairman: W. J. Reichenecker, Westinghouse Electric Corp., East Pittsburgh, Pa.

9:30 am *Engineering and the Future of Castings;* Edgar Belkin, Westinghouse Electric, East Pittsburgh, Pa.

11:00 am *Designing for Performance; the Designer-Foundry Team;* J. Howard Dunn, Aluminum Co. of America, Cleveland.

**STEEL**

Chairman: R. W. Zillmann, Pittsburgh Steel Foundry Co., Pittsburgh, Pa.

9:30 am *Utility of Sand Binder 230 in Steel Foundry Molding Sands;* John L. Dewey, Dow Chemical Co., Pittsburgh, Calif.

10:00 am *Ferro Alloys—Production, Uses and Future Trends;* E. R. Saunders, Union Carbide Metals Corp. Div., Union Carbide Corp., Cleveland.

10:45 am *Deoxidation Practice in Steel Foundries;* John N. Ludwig, Jr., International Nickel Co., Pittsburgh, Pa.

11:30 am *Isotopes in the Radiography of Steel Castings;* Mark Rosumny, Picker X-Ray Corp., Rochester, N.Y.

**SAND SCHOOL**

Chairman: Stewart A. Wick, New Jersey Silica Sand Co., Millville, N.J.

1:30-5:00 pm *Sand Control in the Foundry;* Earl Woodliff, consultant, Foundry Sand Service Engineering Co., Detroit.
*Panelists*—Henry W. Meyer, General Steel Castings Corp., Granite City, Ill.; Larson Wile, Pangborn Corp., Hagerstown, Md.; Thomas C. Jester, Darling Valve & Mfg. Co., Williamsport, Va.; John Fuqua, Cooper Alloy Corp., Hillside, N.J.; Paul W. Green, General Electric Co., Foundry Div., Erie, Pa.

6:15 pm Banquet, Hetzel Union Bldg.
Toastmaster: C. W. Mooney, Olney Foundry, Link-Belt Co., Philadelphia.
Speaker: Frank G. Steinebach, Penton Publishing Co., Cleveland.

## SATURDAY, JUNE 27

**SAND SCHOOL**

Chairman: W. J. Miller, Frederic B. Stevens, Inc., Erie, Pa.

9:30-11:30 am *Sand Control in the Foundry;* George Watson, American Brake Shoe Co., Mahwah, N.Y.
*Panelists*—Edwin J. Richards, Bethlehem Steel Co., Bethlehem, Pa.; Albert Gable, Meadville Malleable Iron Co., Meadville, Pa.; Frank T. Richards, Oil Well Supply Co., Oil City, Pa.; W. S. Hodge, W. S. Hodge Foundry, Inc., Greenville, Pa.

# T&RI Summer Courses Scheduled For Chicago

■ T&RI courses through the summer months will be conducted in Chicago. They include a wide range of subjects involving both instruction and demonstration presentations.

Subjects covered from July through September include *Metallography of Non-Ferrous Metals, Core Sand Practice, Gating & Risering of Castings, Patternmaking* and *Product Development and Marketing.*

### Non-Ferrous Metallography

A demonstration course combining lecture courses and actual sample preparation, examination and analysis. Among the general topics will be physical metallurgy, metallurgy of aluminum alloys, macroscopic and metallographic analysis of copper-base alloys and metallography of magnesium alloys.

### Patternmaking

Demonstration and instruction course dealing not only with wood and equipment considerations, but also plaster and plastic patterns. Other areas will be core blowing, core box design, shell mold and shell core pattern equipment.

### Gating and Risering

Instruction course dealing with both ferrous and non-ferrous metals and includes not only specific recommendations for both metal classes but also general rules applicable to gating and risering in general.

Horizontal and vertical gating will be illustrated in movies, two based on AFS-sponsored research and one from the Institute of British Foundrymen.

### Product Development

Instruction course emphasizing the various factors forcing continual product improvement, not only from competing fabrication methods but also from changing needs of customers. It also stresses how design, cost, quality and service affect the future of the castings industry.

Discussion will be devoted to the advantages of castings and casting design, pattern equipment and selection of the metal.

Topics to be presented on marketing include elements of marketing castings, planning, sales effort, advertising and new product development.

## 1959 T&RI Courses

**July-Sept.**

*Subject and Description* — *Dates*

**Metallography of Non-Ferrous Metals .....July 13-15**
Demonstration and work shop course for melters, supervisors, foremen, foundry engineers, researchers, laboratory technicians, metallurgists and design engineers. Basic metallurgy, terminology, phase diagrams, micro and macro analyses, mechanical properties based on metallographic interpretation and heat treatment are studied. One day on demonstrations and workshop activities in the laboratory. Metal specimens are prepared and studied. Course MTY2A, $80, Chicago.

**Core Sand Practice .....Aug. 10-14**
Instruction covering all phases of materials, mixing and application. The advantages and disadvantages of new materials and methods are studied. Casting losses attributed to cores are analyzed for solutions. Designed for foremen, supervisors, technicians, engineers and management. Course SC1A, $90, Chicago.

**Gating & Risering of Castings .....Aug. 24-26**
Instruction course covering theory and practice on the various problems relating to gating and risering. Metal flow, solidification phenomena, heat transfer, shrinkage, hot tears, ferro-static pressure, gate and riser design, mold wall movement and surface tension are some of the many facets covered. Intended for foremen, technicians, foundry engineers, industrial engineers and production and quality control personnel. Course GR1B, $60, Chicago.

**Patternmaking .....Sept. 16-18**
Demonstration and instruction for patternmakers, foremen, supervisors, trainees, purchasers of castings, suppliers and management—materials, equipment, layout, allowances, construction techniques and recent trends. Emphasis placed on new materials, processes, techniques and their applications. Course PM1A, $80, Chicago.

**Producting Developments & Marketing ....Sept. 28-30**
Instruction course on product analysis from the design to the marketing of the finished product. Study will include: casting design, stress analysis, pattern selection, equipment, cleaning operations, cost analysis, casting processes, engineering properties of cast metals and sales promotion. Scheduled for all types of foundry engineers, sales engineers, technicians, supervisors, metallurgists and management. nel. Course GR1B, $60, Chicago.

***Payment of Tuition Fees should accompany enrollment application. Make all reservations ONLY with Director, AFS Training & Research Institute, Golf & Wolf Roads, Des Plaines, Ill. Tel. VAnderbilt 4-0181.***

# national news

## Chapter Officers Will Study AFS Program

■ Coordination of activities between chapters and the Central Office will be discussed and planned at the 16th Chapter Officers Conference to be held June 11-12 at the Society Headquarters in Des Plaines, Ill. and the Sherman Hotel, Chicago.

Conferees will be divided into groups at the Headquarters June 11 to study various phases of the Society program and will participate in general meetings at the hotel on June 12.

Among the subjects to be covered will be the technical program, AFS Training & Research Institute, membership, MODERN CASTINGS, the Safety, Hygiene and Air Pollution Control Program, AFS finances, planning chapter programs, planning regional programs and regional administration meetings.

Staff members will outline the major activities, emphasizing goals and progress made to date. A question and answer period will be held at each session at Headquarters and a general shakeout period will conclude the program Friday afternoon.

## Advisory Group Urges Continuation of Rochester High Foundry Courses

■ Maintenance and expansion of the foundry course at Edison Technical & Industrial High School, Rochester, N. Y., has been recommended by a Foundry Advisory Committee. Final action on the future of the course will be determined by the Rochester Board of Education and its Vocational Advisory Committee.

The Foundry Advisory Committee was formed to study the advisability of continuing the school's foundry program which has been maintained for several years. For some time its facilities have been housed in separate quarters located at a distance from the main building which includes the patternmaking shop. Classes presently alternate monthly between the two buildings so that one of the shops is idle monthly. Also complicating the problem is the desire to disassociate the foundry classes from the present building.

Members of the committee signing the recommendations were: Donald Webster, American Laundry Machinery Co.; Charles E. Vaughn, and David B. Taylor, Ritter Dental Co., Alfred J. Murrer, Gleason Works, Inc. and Walter G. Brayer, Bausch & Lomb Optical Co. All members are from Rochester, N. Y.

Others assisting the committee were Harold W. Hershey, department head, metal trades, Edison Technical & Industrial High School; local foundrymen and patternmakers and AFS Education Director R. E. Betterley.

Continuation and expansion of the foundry and patternmaking at **Edison Technical & Vocational High School,** Rochester, N.Y., has been recommended by an advisory committee. Participants are **Harold W. Hershey,** head of the school's metals trade department; **Walter Brayer,** Bausch & Lomb Optical Co.; **David B. Taylor,** Ritter Dental Co.; **Donald E. Webster,** American Laundry Machinery Co.; **Alfred J. Murrer,** Gleason Works, Inc.; **Fletcher Miller,** chief consultant, Board of Education.

## Groups to Start Training Survey

■ A study of technical training needs of small foundries in the Cincinnati, Birmingham and Minneapolis-St. Paul areas has been proposed. The program designed to promote training in the foundry industry, will be conducted through the cooperation of the U. S. Dept. of Labor, Bureau of Apprenticeship & Training and the education committees of the AFS chapters in these areas.

Local groups will study types of training needed, recommend methods for training and provide general stimulation and coordination of training programs. This would include making use of the services of the AFS Training & Research Institute program, vocational schools, colleges, Bureau of Apprenticeship & Training and other agencies.

This program was proposed at a meeting of the National Foundry Advisory Committee during December in Washington, D. C., with representatives from the Bureau of Apprenticeship & Training.

Attending were: AFS Director of Education R. E. Betterley; Roy A. Gezelius, General Steel Castings Corp., Eddystone, Pa.; Charles T. Sheehan, National Foundry Association, Chicago; P. E. Rentschler, Hamilton Foundry & Machine Co., Hamilton, Ohio; F. G. Steinebach, Penton Publishing Co., Cleveland; B. C. Yearley, National Malleable & Steel Castings Co., Cleveland.

## Sanders, Massari Madrid Delegates

■ National Director Clyde A. Sanders, American Colloid Co., Skokie, Ill., and AFS Technical Director S. C. Massari have been named as official AFS delegates to the 26th International Foundry Congress to be held Oct. 4-10 in Madrid, Spain.

C. A. Sanders

S. C. Massari

AFS will sponsor two escorted tours to the International Congress. Details will be announced in future issues of MODERN CASTINGS.

# Instructors Seminar

■ A combination of basic foundry principles and the latest in metal-casting techniques will be presented to secondary-level foundry and pattern-making instructors at the 4th AFS Foundry Instructors Seminar.

Included in the three-day program, June 18-20, will be teaching aids, discussion of curricula, shop layout, laboratory facilities, casting methods, techniques and applications, in-plant training, career opportunities and an inspection trip.

The Seminar is sponsored by the AFS Education Division and is to be held at the University of Illinois, Urbana, Ill., in cooperation with the school's Division of University Extension.

Co-Chairmen for the Seminar are Prof. Roy W. Schroeder, University of Illinois, Navy Pier, Chicago, and Vice-Chairman of the Education Division; and Ralph E. Betterly, AFS Education Director.

AFS in cooperation with the Society's chapters will assume all Seminar expenses of accepted conferees while in Urbana including hotel rooms, meals, programs, materials and foundry inspection trip.

**THURSDAY, JUNE 18**

9:00 am—Registration (Illini Union Ballroom, second floor).

10:00 am—Welcome and Orientation, R. E. Betterley, AFS Education Director.

10:15 am—Welcome to University, Dr. Gordon Ray, Vice-President, University of Illinois. (Castings in the future, new materials, applications, challenge to engineered castings).

10:40 am—"AFS Activities," A. B. Sinnett, AFS Secretary, (Technical committees, publications, T&RI, research, education, convention and exhibits).

11:00 am—"Sand in the School Foundry," V. M. Rowell, Harry W. Dietert Co., Detroit. (Selection, conditioning, control additives, equipment).

1:00 pm—"School and Plant Liaison," R. A. Oster, Beloit Vocational & Adult School, Beloit, Wis. (Coordinating the school program, cooperative plans, advantages, school and industry responsibilities).

1:45 pm—"Ventilation for the School Foundry," H. J. Weber, Director of Safety, Hygiene and Air Pollution Control. (Equipment, methods, safety, meeting requirements and dangers.)

2:30 pm—"Wood Patternmaking in the School," F. C. Cech, Max S. Hayes Trade School, Cleveland. (Basic principles, teaching, levels of instruction, apprentice contest, coordination with the foundry).

3:15 pm—"Administrative Problems in Setting Up School Foundries," E. M. Claude, Illinois Board of Vocational Education, Springfield, Ill. (Incentives, foundry work in educational programs, resolving problems).

4:00 pm—Group Picture.

5:15 pm—Dinner and Field Trip, (Inspection of Central Foundry Div., GMC, Danville, Ill.).

**FRIDAY, JUNE 19**

9:00 am—"Making Crucible Furnace for School Use," Dr. C. G. Risher, Western Michigan University, Kalamazoo, Mich. (Materials, methods, cost, use and operation).

10:00 am—Demonstration Workshops Orientation, Prof. J. L. Leach, University of Illinois.

10:20 am—Demonstration Workshop Briefs (Melting, molding, coremaking, $CO_2$ and shell molding, sand testing, wood patternmaking).

1:00 pm—Demonstration Workshops.

3:00 pm—Pouring Instructions, Prof. J. L. Leach.

3:15 pm—Pouring the Heat.

7:00 pm—Banquet, Urbana-Lincoln Hotel. Guest Speaker, Wm. W. Maloney, AFS General Manager.

**SATURDAY, JUNE 20**

8:30 am—"Instructional Aids and Materials," T. H. Boardman, Division of University Extension, University of Illinois. (New developments, materials, methods, visual aids, demonstrations and applications).

10:15 am—Planning and Equipping a School Foundry

"Selling the Program," John Strange, Sterling Township High School, Sterling, Ill.

"Shop Layout & Equipment," Joseph Madru, Sherman High School, Chillicothe, Ohio.

"Course of Instruction," Andrew Bottoni, Milwaukee Vocational & Adult School, Milwaukee.

"Teaching the Program," Robert Speerbrecker, Wisconsin State Department of Vocational & Adult Education, Madison, Wis.

11:30 am—Shakeout (Question and answer period).

12:00 am—Getaway Luncheon.

1:00 pm—Evaluation Meeting.

# Radiation Manual Now Under Review

■ Final drafts of the AFS Radiation Protection Manual are under review by members of the AFS Safety, Hygiene & Air Pollution Control Steering Committee and the Radiation Protection Committee.

Purpose of the manual is to . . . "develop and describe radiation protection controls for the foundry industry which will prevent injury, minimize medico-legal entanglements and provide a sound foundation upon which legislative controls can be built."

The book is divided into seven chapters and a glossary. These chapters and their contents are:

**Nature and Sources of Radiation in the Foundry**—provides basic information about the characteristics in general, and describes the sources of radiation presently being used in foundries.

**Health Aspects of Radiation**—contains biological and medical information designed to dispel fears and gives an understanding of what is being protected against in a radiation protection program.

**Control of Radiation in the Foundry**—has specific details and procedures for the installation and use of a radiologically safe radiation facility.

**Radiation Detection Instrumentation**—outlines the theory of radiation detection and counting and a description of the use of this equipment in a foundry.

**Protection by Shielding and Distance**—describes the phenomena involved in shielding and the formulae and empirical data required for calculating specific applications.

**Procedures for Handling and Use of Sources of Radiation**—presents techniques developed by industries pioneering radioisotope use with existing regulatory guidelines.

Congratulating national apprentice winners was one of last acts by **L. H. Durdin,** AFS President 1958-59. First place winners shown in front are: **Horst N. Prohaska,** wood patternmaking; **Stanley Graff,** non-ferrous molding; **Forest Wills,** iron molding; **L. S. Uveges,** metal patternmaking; **Robert Lord,** steel molding. Second place winners are: **Darrell A. Giles,** wood patternmaking; **Alfred A. DiRaimo,** iron molding; **Zane Holowachuk,** metal patternmaking; **James Fazio,** steel molding. Missing was Ronald McConnville, non-ferrous molding.

# Twin City Seminar Attracts More Than 300

J. David Johnson
*J. David Johnson Co.*
*Anoka, Minn.*

**Frank S. Ryan,** Twin City Casting Seminar chairman (left) checks on speakers about to discuss new casting processes.

Crowd at one of four sessions of **Twin City Casting Seminar** co-sponsored by the AFS Twin City Chapter and the University of Minnesota.

■ More than 300 current and potential casting customers in the Minneapolis-St. Paul Twin City area attended the second Biennial Engineered Castings Seminar presented by the AFS Twin City Chapter in cooperation with the University of Minnesota. Meetings were held on four consecutive Mondays in March at the University's Mechanical Engineering Building, Institute of Technology, Minneapolis.

The Seminar was planned by the chapter's seminar chairman, Frank S. Ryan, St. Paul Brass Foundry, St. Paul, and aided by committee members John Entenmann, Northern Malleable Iron Co., St. Paul, Minn., John Wallfred, Minneapolis Electric Steel Castings Co., Minneapolis, and Dave Johnson, J. David Johnson Co., Anoka, Minn.

All technical papers were directed toward casting buyers and designers and were linked to the theme "Economics of Engineered Castings." The average attendance double that of the first seminar held in 1957. No fee was charged for the seminar.

The opening session was devoted to "Proper Design and Specifications." John B. Caine, consultant, Cincinnati, spoke on ferrous metals and William Ball, R. Lavin & Sons, Chicago, discussed non-ferrous metals.

"Customer-Supplier Relations," was the topic at the second meeting in which Clinton C. Forster, Toro Mfg. Co., Minneapolis, spoke on the castings customer point of view and Donald A. Moll, Minneapolis Electric Steel Castings Co., Minneapolis, gave the views of the castings producer.

"Castings Economics" was the subject of the third session. A round-table discussion was held, comparing castings to other metalworking processes. Advantages of the different processes were discussed.

Members of the round-table were: N. E. Qualey, Northern Ordnance, Inc., Minneapolis; K. F. Potter, American Hoist & Derrick Co., St. Paul, Minn.; Phillip E. Gustafson, Minneapolis Honeywell Regulator Co., Hopkins, Minn.; Donald Fulton, Northern Malleable Iron Co., St. Paul, Minn. A film, "Photo Elastic Studies of and Weldments," produced by the Steel Founders' Society completed the third program.

Five specialists in various casting fields discussed "What Do New Processes for Producing Castings Accomplish," at the final session.

Participants and their subjects: Arthur Johnson, Northern Malleable Iron Co., St. Paul, Minn., "Better Dimensional Control of Castings Cavities Through the Use of Shell and $CO_2$ Cores;" Merle Weltzin, Progress Foundry, Inc., St. Paul, Minn., "Close Tolerances and Excellent Surface Finishes for Semi-Production and Production Runs of Aluminum Castings through Permanent Molds;" Lynn Charlson, Char-Lynn Co., Minneapolis, "High Production Zinc and Aluminum Castings Via the Die Casting Process;" Wayne A. Wright, Woodruff & Edwards, Inc., Elgin, Ill., "Dimensionally Controlled, Improved Surface Finish, Low Cost, Small, Ferrous and Non-Ferrous Castings through Shell Molding;" Clayton Brace, Inc., Minneapolis, "Small Precision Castings through Investment Process Result in Lower Tooling Costs."

**J. B. Caine,** foundry consultant, and Twin City Chapter Chairman **Robert J. Mulligan** get down to cases at Twin City Castings Seminar.

**Twin City Casting Seminar** chairman Frank S. Ryan appears as mock referee between casting producer A. Donald Moll on left and casting buyer Clinton C. Forster on right.

# chapter news

**Northeastern Ohio Chapter**

## Sponsors Aluminum Workshop

■ High school foundry and pattern-making instructors in the greater Cleveland area on March 24 attended an aluminum foundry workshop sponsored by the Education Committee of the AFS Northeastern Ohio Chapter.

Apex Smelting Co., Cleveland, was host to the workshop which was directed by Edward Trela, Apex research metallurgist.

Included in the program were demonstrations and work sessions in melting, fluxing and pouring of aluminum alloys in sand and permanent mold castings. Quality control and inspection castings as well as pressure die cast-methods were also demonstrated.

**St. Louis Chapter**

## Conducts Spring Dance

■ More than 200 St. Louis Chapter members and their wives attended the annual spring dance held March 11 at the Norwood Hills County Club.

**San Antonio Section**

## Has Two Films During April

■ Two films were shown at the April meeting held at Alamo Iron Works, San Antonio, Texas. Thirty-one members and guests attended.

"Segregation of Sands" showed experiments in sand storage and transfer and how segregation was present each time sand is moved. Various methods were shown to minimize the mixing of sand sizes.

"Take It Away" illustrated various types of slings and their uses.

**Tri-State Chapter**

## Discusses New Foundry Methods

■ New methods in foundry operations were discussed at the April meeting by a five-man panel headed by moderator R. W. Trimble, Bethlehem Supply Co., Tulsa, Okla.

The speakers and their subjects: L. L. Clark, Fansteel Metallurgical Corp., Muskogee, Okla., "Metallurgy;" Dale Davis, Oklahoma Steel Castings Corp., Tulsa, Okla., "Mechanical Maintenance;" J. O. Crider, Bethlehem Steel Co., Tulsa, Okla., "Safety and Accident Prevention;" James E. Reedy, Hill & Griffith Co., Birmingham, Ala., "Sand Development;" Lloyd M. Rose, M. A. Bell Co., St. Louis, "Equipment and Tools." *—Leslie O'Brien*

**British Columbia Chapter**

## Casting Inspection for Profit

■ Non-destructive testing should be used to develop the proper pattern-making and casting techniques and used thereafter as a control measure or selected sampling rather than for 100 per cent inspection of finished products. This advice was given at the April meeting by Kermit Skeie, Magnaflux Corp., Los Angeles.

He stressed that the tests should be performed as early as possible in the work schedule to avoid costly cleaning and machining. Skeie provided design hints to decrease stress concentration and weight.

*—A. W. Greenius*

**Metropolitan Chapter**

## What is Expected of Castings

■ What is expected of a casting was outlined by a three-man panel at the April meeting. J. W. Foster, buyer, Ingersoll-Rand Co., emphasized the importance of quality, service, delivery and cost.

Albert W. Mead, engineer, Grumman Aircraft Corp., pointed out possible future uses of castings if aircraft standards could be met.

William H. Baer, Department of Army, Fort Belvoir, Va., stressed the importance of correct gating and risering methods and the knowing of all of the requirements applicable prior to production.*—C. H. Fetzer*

**Twin City Chapter**

## Hears Talk on Pressure Molding

■ Improvements in green sand foundries attainable through high pressure molding techniques can produce improved quality and productivity needed to meet today's competition said W. F. Adams, Eastern Clay Dept., International Minerals & Chemical Corp., Skokie, Ill.

However, Adams emphasized that careful investigation must be made by foundrymen prior to acquiring pressure molding equipment. The three requisites of pressure molding are: good pattern practice with strong, rigid, accurate flasks; high moldability sand only somewhat different from a typical synthetic green sand; and a molding pressure or means to get satisfactory mold hardness on vertical mold walls near the parting.*—J. David Johnson*

**Northeastern Ohio Chapter**

## Designing for Serviceability

■ Factors to consider in designing a product include strength requirements, corrosion resistance, rigidity, pressure tightness, finish and soundness, among others. Of these, the foundryman has control over only a few, said J. H. Dunn, Aluminum Co. of America, Cleveland, at the March meeting.

Experience in casting production eases the foundryman's job because such knowledge enables him to avoid designs which require complicated molding operations.

Dunn described briefly the development laboratory and staff of his firm and its procedures in developing suitable casting designs. A motion picture depicted field testing of a combination of an aluminum forging and an aluminum casting for suspension of tandem rear axles for trucks.

*—Edwin Bremer*

## Michigan Regional Oct. 8-9

■ The 1959 Michigan Regional Conference will be held Oct. 8-9 at the Pantlind Hotel, Grand Rapids, Mich. David I. Jacobson, Grand Haven Brass Foundry, Grand Haven, Mich., is Conference Chairman. Vernon J. Sadler, General Foundry & Mfg. Co., Flint, Mich., is program chairman.

**Central Ohio Chapter**

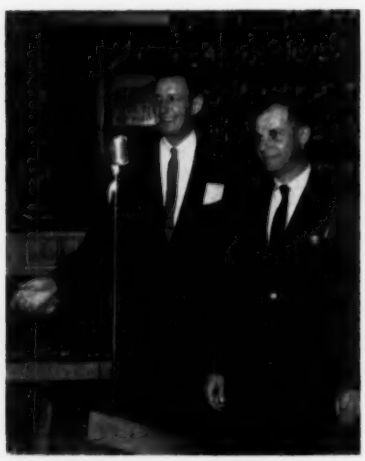
## Education in the Foundry

■ Apprentices entering local and national competition gain more than mere mechanical skills, said B. D. Claffey, Dayton Malleable Iron Co., Dayton, Ohio, in addressing the April meeting. Among the other benefits are integrity, ambition, desire to improve, pride in accomplishment and willingness to cooperate. Claffey predicted a bright future for apprentices, pointing out that many of the challenges facing apprentices are the same as those facing the foundry industry. *—Joseph A. Riley, Jr.*

**Kermit Skeie,** Magnaflux Corp., shown on left, meets with Program Chairman **Fred Young,** Chapter Chairman **Leon Morel** and Vice-Chairman **Vern Rowe** prior to the start of the Washington Chapter April meeting. Skeie discussed "Casting Inspection for profit."

Seated at head table during March meeting of **Western New York Chapter** are: Chapter Director **W. J. Mosier,** Economy Pattern & Pressure Cast Products; Chapter Publicity Chairman **Donald Krueder,** Foundry Services, Inc.; **G. F. Goetsch,** Sterling Industries, Inc.

**T. W. Curry,** Lynchburg Foundry Co., Lynchburg, Va., spoke to the March meeting of the **Piedmont Chapter** on "Shop Methods and Control of Ductile Iron Castings." He illustrated standard procedures and innovations used in the process. Detrimental effects and inhibitors of quality in ductile iron castings were reviewed. —**H. R. Fisher**



Technical Chairman **A. Litzau,** Carondelet Foundry Co., St. Louis, introduces **John Chahbandour,** Carrier Conveyor Corp., Louisville, Ky., who addressed chapter in April on vibrating conveyors. —**Vince Boemer**

**Northeastern Ohio Chapter**

## April Meeting Has Two Speakers

■ Two speakers were featured at the April meeting held at the Tudor Arms Hotel.

R. A. Clark, Electromet Div., Union Carbide Corp., Cleveland, spoke on "Solidification and Heat Treatment of Gray Iron, Ductile Iron and Alloy Iron." Clark's talk, also given during March at the chapter's technical symposium of cast metals, was presented at the chapter's April meeting in response to requests. Alex Barczak served as technical chairman.

The second speaker was M. K. Young, U. S. Gypsum Co., Chicago, who spoke on "Plaster and Plastics Materials for the Foundry Industry."

**Central New York** Chapter Vice-Chairman **Bruce R. Artz,** Pangborn Corp., Syracuse, N.Y., admires birthday cake presented at February meeting. Others are **William Thomas,** Straight Line Foundry & Machine Corp. and **Edward Fieseinger, Jr.,** Crouse-Hinds Co., both of Syracuse,N.Y.

Attending April meeting of **Central Indiana Chapter** left to right: **Frank Button,** Haynes, Stellite Co., Kokomo, Ind.; **Chuck Everhart,** Central Foundry Div., GMC, Danville, Ill.; **Warren Ballintine,** Haynes Stellite Co., Kokomo, Ind.; and **John Hastings,** Electrometallurgical Co., Indianapolis. —**Wm. R. Patrick**

Human engineering was discussed at the **Tennessee Chapter** meeting by W. M. Ball, Jr., R. Lavin & Sons, Inc., Chicago. Shown are Regional Vice-President **Karl L. Landgrebe, Jr.,** Wheland Co., Chattanooga, Tenn.; **speaker Ball;** Tennessee Chapter Chairman **W. L. Austin,** U. S. Pipe & Foundry Co., Chattanoga, Tenn.; Chapter Vice-Chairman **Charles E. Seman,** Crane Co., Chattanooga, Tenn.

**Wayne Watson,** (right) Olney Foundry Div., Link-Belt Co., Philadelphia, congratulates and presents Philadelphia Chapter's award to **Forrest Wills.** Wills of Olney Foundry, won first place in iron molding the AFS Robert E. Kennedy Memorial Apprentice Contest.
—**Leo Houser and E. C. Klank**

Unidentified beast in center fails to see the humor expressed by **Dr. D. E. Cutler,** J. S. McCormick Co., Pittsburgh, Pa., (center) and Texas Chapter Chairman **Harold Judson,** University of Houston. Picture taken at Texas Regional Foundry Conference.—**O. J. Myers**

Richard C. Meloy, marketing director, Gray Iron Founders' Society, spoke at the March meeting of the **Philadelphia Chapter** outlining how castings can be better marketed. In photo: **speaker Meloy;** Technical Chairman **M. E. Neeley, Jr.,** Dodge Steel Co., Philadelphia; Chapter Chairman **T. R. Walker, Jr.,** U. S. Pipe & Foundry Co., Burlington, N. J.

# chapter news

Plaques were awarded past chairmen of the Texas Chapter at the Texas Regional Foundry Conference held in March. Former chairmen and their years of office: **C. R. McGrail,** 1949-50; **Jake Dee,** 1948-49; **E. P. Trout,** 1945-46; **F. M. Wittlinger,** 1943-45; **J. M. Bird,** 1951-52; **E. C. Brown,** 1957-58; **J. R. Hewitt,** 1955-56; **E. W. Wey,** 1954-55; **M. W. Williams,** 1947-48; **W. A. Bearden,** 1956-57; **P. B. Croom,** 1952-53.

New England Chapter President **William Ohlson,** Draper Corp., Hopedale, Mass., (left) congratulates April speaker **Dr. Charles P. Kindleberger,** Massachusetts Institute of Technology, Cambridge, Mass. In center is **W. Scott Lattimer,** president, Student Chapter at M.I.T. Kindleberger, speaking at the meeting held in the Sloan Building at M.I.T., discussed "Changing Patterns in U.S. Foreign Trade." Included was a discussion of international trading in metals, fabricated and cast parts made in the United States. Kindleberger stated that the heavy goods industries are constantly affected by this changing scene. **—J. H. Orrok and F. W. Holway**

**F. M. Wittlinger,** first chairman of Texas Chapter (left) presents past chairman's plaque to **H. H. Judson,** chairman 1958-59.

**Central New York** Chapter Chairman **R. J. Denton,** Denton Refractory Service Corp., Syracuse, N.Y., cuts cake marking chapter's 25th anniversary. Others are **William Mader,** Oberdorfer Foundries; **H. J. Weber,** AFS Director of Safety Hygiene & Air Pollution Control and Chapter Vice-Chairman **Bruce R. Artz,** Pangborn Corp., Syracuse, N.Y.

**N. W. Meloon, Jr.,** Meloon Bronze Foundry, Syracuse, N.Y., holds plaque he received on being inducted into past chairman's club. Others are **William Nader,** Oberdorfer Foundries and a past chairman; and chairman **R. J. Denton.** **—Carl Diehl**

**Northwestern Pennsylvania** members at the March meeting heard T. W. Curry, Lynchburg Foundry Co., Lynchburg, Va., discuss "Shop Method and Control of Ductile Iron Castings." Shown are: Chapter President **W. S. Hodge** Foundry, Inc., Greenville, Pa.; speaker Curry and Technical Chairman **W. R. McCracken,** Cooper-Bessemer Corp., Grove City.

**W. F. Adams** addressing **Twin City Chapter** in April on pressure molding. **—J. David Johnson**

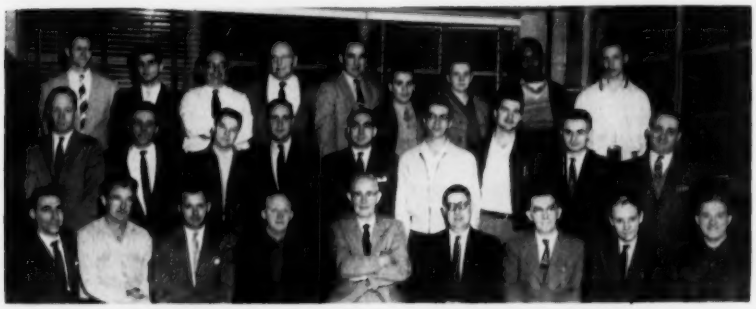
**Lindsay Cooper,** Canada Iron Foundries, Ltd., and a member of the entertainment committee, presents **Mrs. John Hughes** with flowers at the Ontario Chapter's Annual Ladies Night held in April. **—Vincent H. Furlong**

Attending **New England Chapter's** April meeting are **A. M. Nutter,** president, Gray Iron Founders' Society; **Lewis W. Greenslade,** Brown & Sharpe Mfg. Co., Providence, R.I.; **Richard C. Meloy,** marketing director, Gray Iron Founders' Society; **Charles F. Walton,** technical director, Gray Iron Founders' Society. **—J. H. Orrok and F. S. Holway**

**Henry E. McWane,** Lynchburg Foundry Co., Lynchburg, Va., holds bell presented by Chapter Chairman **D. E. Matthieu,** far right, Wysong & Miles, Co., Greensboro, N.C. Bell is emblematic of 40 years membership in AFS. Others in picture are **Andre Renard,** Glamorgan Pipe & Foundry Co., Lynchburg, Va.; and **W. W. Levi,** Lynchburg Foundry Co. **—H. R. Fisher**

# chapter news

**Western New York** Chapter officers and committee for annual spring dance. Standing: Vice-Chairman **A. J. Heysel, Robert D. Young, Gerald Goetsche,** Chairman **L. B. Polen, William Moser** and **Phil Block**. Seated: **Mrs. Young, Mrs. Goetsche, Mrs. Polen, Mrs. Mosier** and **Mrs. Block.** —**Don Krueder**



Participants in **Philadelphia Chapter's** educational program tour Philadelphia Coke Co. facilities. Shown in front row are: far left, **E. X. Enderlein,** chairman of the chapter's education committee; fourth from right, guide **H. Cluley;** second from right, guide **H. DeHoll;** far right, **Ed Saks,** foundry instructor, Dobbins Vocational and Adult School, Philadelphia.—**Leo Houser**

Representing Dodge Steel Co., Philadelphia, at **Philadelphia Chapter** meeting are (front row): **V. Stampone, J. Mooney, J. Fitzgerald, M. Neeley,** Jr. Back row: **R. J. Johnston,** Chapter photographer **Leo Houser, R. J. Campbell, A. S. Breithaupt,** Chapter Vice-Chairman **E. A. Zeeb.** —**Leo Houser, Ed Klank**

**Chicago Chapter**

## Conducts Simultaneous Sessions

■ Simultaneous sessions for five of the chapter's divisions were conducted at the April meeting.

Irwin Lubalin, Shaw Process Development Corp., Port Washington, N. Y., discussed "Shaw Process for Casting Dies and Permanent Molds." He stressed the wide range of sizes now being produced by the process and also exhibited missile and aircraft castings made in tool steels and super alloys.

J. F. Wallace, Case Institute of Technology, Cleveland, spoke on "Gating and Risering of Gray Iron." He outlined the principles for both gray iron and ductile iron castings. Methods of actually calculating gating and risering systems for specific castings were also covered.

Art Johnson, Northern Malleable Iron Co., St. Paul, Minn., brought foundrymen up to date on "Shell Cores and Their Practical Use." He based his talk on problems encountered by Northern Malleable and how they were solved. He also emphasized the closer tolerances now possible and how they can be obtained.

Franz Bergquist, National Malleable & Steel Castings Co., Cicero, Ill., spoke on "General Foundry Maintenance Problems," outlining a maintenance program for speed reducers, sand handling equipment, belt conveyors, shakeout and sand mullers.

F. W. Boulger, Battelle Memorial Institute, Columbus, Ohio, addressed the steel session on "Effects of $H_2$ and $N_2$ on Ductility and Porosity of Castings." He pointed out that hydrogen is picked up from refractories and furnace atmospheres and precipitates as a gas. Nitrogen is picked up from furnace atmosphere and precipitates as an intermetallic compound. Nitrogen is a potent strengthening agent and lowers ductility. Nitrogen helps to control grain size and can be used to improve Charpy transition temperatures.

## How Others Are Doing It

**Chapter Programs**

A theme is selected for the entire year's program by the Northeastern Ohio Chapter with each technical session dealing with the some phase of the theme. The chapter recommends that the program be completed in June for the following year so that speakers are assured.

## afs chapter meetings

JUNE

**Central New York . . June 20** . . Hinerwadel's Grove, N. Syracuse, N.Y. . . *Clam Bake.*

**Chesapeake . . June 5** . . Hagerstown, Md. . . *Plant Visitation to Pangborn Corp. and Fairchild Engine & Aircraft Corp.*

**Cincinnati District . . June 8** . . Walnut Grove Country Club, Dayton, Ohio . . *Golf Outing and Picnic.*

**Detroit . . June 27** . . Glen Oaks Country Club . . *Annual Golf Outing.*

**Mexico . . June 29** . . Ave. Chapultepec 414, Mexico, D.F. . . R. Jauregui, Aceros Tepeyac S.A., *"Practical Metallography."*

**Northeastern Ohio . . June 27** . . Barberton Brookside Country Club . . *Annual Outing and Golf Party.*

**Northern California . . June 13** . . Sequoia Country Club . . *Ladies' Night.*

**Oregon . . June 17** . . West Linn Inn, West Linn, Ore. . . Plant Tour, Crown Zellerbach Paper Corp.

**Pittsburgh . . June 8** . . Churchill Valley Golf Club . . *Annual Golf Party.*

**Saginaw Valley . . June 6** . . I.M.A. Lodge, Potter's Lake . . *Annual Outing.*

**Southern California . . June 12** . . Rodger Young Auditorium, Los Angeles . . *Past President's Night.*

**Texas . . June 6** . . Fredonia Hotel, Nacogdoches, Texas . . *Family Week End.*

**Western New York . . June 20** . . Sturm's Grove, Buffalo, N. Y. . . *Annual Stag Outing.*

JULY

**Philadelphia . . July 17** . . Manufacturers Golf & Country Club, Oreland, Pa. . . *Annual Summer Outing.*

**Wisconsin . . July 24** . . *Annual Outing.*

Plaster and plastic materials for the foundry were discussed at the April meeting of the **Northeastern Ohio** Chapter by M. K. Young, U. S. Gypsum Co., Chicago. Shown are: **Don Hartman,** Cove Pattern Works, Cleveland; **Eldon Whiteside** and **M. K. Young,** U. S. Gypsum Co.; **John Roth,** Cleveland Standard Pattern Co. —**Harold Wheeler**

Speaker **Samuel F. Carter,** American Cast Iron Pipe Co., Birmingham, Ala. (left) and technical chairman **Harold L. Kurtz,** Empire Steel Castings, Inc., Reading, Pa., shown at April meeting of Philadelphia Chapter. Carter spoke on "Electric Furnace Melting," discussing factors affecting quality.
—**Leo Houser and E. C. Klank**

**J. E. Haller,** James B. Clow & Sons, Coshocton, Ohio, chairman of the Central Ohio chapter apprentice contest, presents $25 check to **Arlen Munsey,** Ohio Steel Foundry Co., Springfield, Ohio, 1st place winner in the pattern competition. Others are **Darrell Sickle,** Ohio Steel Foundry Co., 2d place, pattern competition; **Willie Gaines,** Ohio Steel Foundry Co., 1st place steel molding; **Charles Jewell,** Burnham Corp., Zanesville, Ohio, 1st place, gray iron molding; **Robert Ruff,** Alten Foundry & Machine Works, Inc., Lancaster, Ohio, 2nd place, gray iron molding. Not shown is Robert Higgins, Cooper-Bessemer Corp., Mt. Vernon, Ohio, 3d place, gray iron molding. First place winners received $25 and second place winners $15. —**Joseph A. Riley, Jr.**

More than 350 foundrymen and their wives attended the **Ontario Chapter's** Annual Ladies Night held in April at the Seaway Hotel, Toronto, Ont. Chuck Bateman, Hamilton Facing Mill Co., Ltd., was the entertainment chairman. Shown at left are **Mr. & Mrs. W. Bain** and **Mr. and Mrs. Vincent H. Furlong.** Bain is superintendent of Canada Iron Foundry and Furlong, Foundry Services (Canada) Ltd., is the chapter publicity chairman.

**Philadelphia** Chapter Chairman **T. R. Walker, Jr.** (second from left, last row) with 21 men from the U. S. Pipe & Foundry Co., Burlington, N. J. Walker is resident manager of the plant. The group attended the April Philadelphia Chapter meeting.

WHO'S GOT HANDLEBAR HARRY?

Circle No. 167, Page 141-142

FORWARD DUMP BARROWS for FOUNDRIES

No. 102-A Barrow. Single steel wheel with 2" face, 16" diameter and 12 spokes.

No. 113-A Barrow. Two steel wheels with 2" face, 18" diameter and 10 spokes.

Here are two well-balanced charging Wheelbarrows for heavy duty foundry service. Handle loads up to 1000 lbs. Sturdy, welded, all-steel construction. Single wheel or double wheel. Available with zero pressure cushion type wheels or 4 ply pneumatic tired wheels with roller bearings. Immediate shipment.

*Write for literature.*

STERLING NATIONAL INDUSTRIES, Inc., Milwaukee 14, Wis., U. S. A.
Founded 1904 as Sterling Wheelbarrow Company

Sterling FOUNDRY EQUIPMENT

Circle No. 168, Page 141-142


## let's get personal

*Continued from page 22*

Corp., Detroit, is now production manager, Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn.

**Alex D. Barczak** and **Lloyd W. Leeseberg** . . . have been elected as directors of Superior Foundry, Inc., Cleveland. Leeseberg replaces Warren W. Brown.

**C. E. Gillespie** is now vice-president of Debevoise-Anderson, Inc., Boston, with his office in Philadelphia. He is a member of the AFS Philadelphia Chapter.

**J. N. Ludwick** . . . purchasing agent, Universal-Rundle Co., Camden, N.J., and a member, AFS Philadelphia Chapter, has retired.

**D. MacBrien** . . . was recently promoted to general sales manager, Philadelphia Coke Div., Eastern Gas & Fuel Associates. He holds a membership in the AFS Philadelphia Chapter.

**J. Lanning** . . . president, Perseverance Iron Foundry, Philadelphia, has announced his retirement. He is a member, AFS Philadelphia Chapter. **P. Lanning,** former secretary-treasurer, will assume duties as president.

**John M. Perkins** . . . formerly promotion manager of the American Car & Foundry Division, ACF Industries, has been named as director of industrial product sales.

**Luis Valdivieso** . . . has been transferred to San Juan, Puerto Rico, to supervise sales in the Caribbean and Central American territory for Mexico Refractories Co., Mexico, Mo.

**Karl K. Breit** . . . now heads sales engineering department for Richard C. Remmey Son Co., Philadelphia, subsidiary of A. P. Green Fire Brick Co., Mexico, Mo.

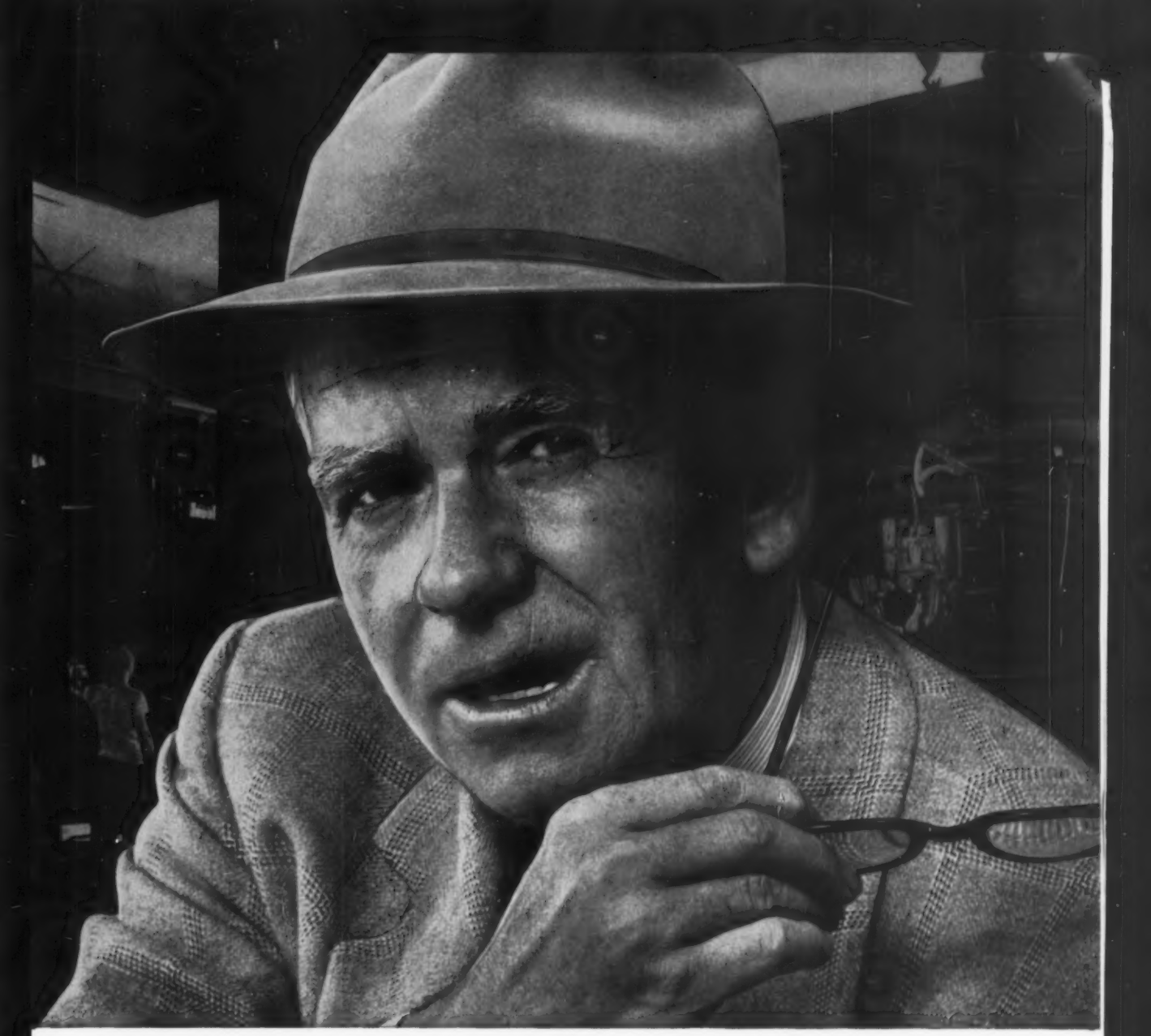
**C. D. Matthews** . . . has been elected as president, Standard Buffalo Foundry Co., Buffalo, N. Y. Other officers are: vice-president, **Charles Matthews;** secretary-treasurer, **John W. Burns.**

**George Costas** . . . formerly foundry manager, Studebaker-Packard Co., is now foundry plant manager, Curtiss-Wright Corp., Metals Processing Div., Buffalo, N. Y.

**Tom Weidig** . . . has been promoted to superintendent, foundry engineering, Curtiss-Wright Corp., Metals Processing Div., Buffalo, N. Y.

**L. N. Schuman** . . . will head the new product engineering department, Industrial Div., National Malleable & Steel Castings Co., Cleveland. His position will entail conversion of competing materials

*Continued on page 118*



# *"We use only one chrome—refined chrome"*

Iron and steel foundry operators are cutting chromium costs by using ELECTROMET's new low-cost refined chrome for all high-carbon chromium additions. Inventory, handling, and storage are greatly simplified by stocking only this one high-carbon chromium alloy. It is ideal for use as:

- **A charge material for basic-melted stainless steel.**
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- **Cupola or ladle additions for cast iron.**

Refined charge chrome combines the economy of regular charge chrome with the maximum cleanliness and low residual element content of conventional high-carbon ferrochrome. For facts on how refined chrome can reduce your costs, contact your UNION CARBIDE METALS representative.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

Convenient 20- and 40- pound pigs of refined chrome are magnetic, allowing easy handling with an electromagnet. Crushed sizes are available for ladle additions.

UNION CARBIDE METALS

***Electromet** Brand Ferroalloys and other Metallurgical Products*

The terms "Electromet" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

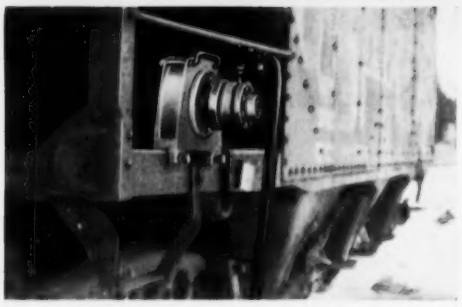
**Circle No. 169, Page 141-142**

WHO'S GOT
HANDLEBAR HARRY?

Circle No. 170, Page 141-142

VIBROLATOR®

Heavy duty vibration inducer
SOLVES COKE UNLOADING PROBLEMS



This light weight vibrator has been proved 100% effective for removal of coke from hopper cars.

**High-amplitude vibrations • Shock and spark proof • Pneumatically driven • Quiet operation • Precise control through a range of a few cycles per second to 60 cycles per second**

Starts wet or dry materials moving—and keeps them flowing from railroad cars, massive hoppers, bins, chutes or conveyors. Pneumatically driven, the CCVP operates at low-noise level in all frequencies. Portable, with its own mounting clamps, unit can be mounted in any position or angle convenient to the job. Unconditionally guaranteed to give satisfaction.

*"Vibrolator" is Martin Engineering's registered trade mark for its vibration inducers and vibrator accessories.

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**MARTIN ENGINEERING COMPANY 155 Aman Ave. Neponset, Illinois**

"Vibrolator" vibrators are available in a wide range of sizes "pocket watch" to the most powerful hand-portable unit built.

Circle No. 171, Page 141-142


## let's get personal

*Continued from page 116*

to malleable iron, pearlitic malleable and steel castings. **Lovell Shockey** will succeed **D. L. Griffith** as sales manager, Cleveland Works, Griffith will become sales coordinator.

**J. W. Higley** . . . is the new district representative for the Buffalo territory, Foundry Equipment Co., Cleveland. **J. L. Patterson** has been appointed district representative for the Philadelphia territory.

**L. W. Wagners** . . . appointment as Augusta district manager has been announced by Pangborn Corp., Hagerstown, Md. He is a veteran in the blast cleaning and dust control fields and has been with the firm since 1926.

**G. N. Wright** . . . has joined Solon Foundry, Inc., Solon, Ohio, as director of sales.

## obituaries

**Frederick W. McWane,** assistant to the president, Lynchburg Foundry Co., Lynchburg, Va., died March 3. He was a civic and church leader, associated in official capacities with educational and public institutions, and was fatally stricken while addressing a Junior Chamber of Commerce meeting.

**Dr. Marcel Ballay,** Centre d'Information Du Nickel, Paris, France, died recently. He was an official French delegate to the 1952 International Foundry Congress held in Atlantic City.

**George E. Dalbey,** 72, who moved to Florida after retiring from the Mare Island Naval Shipyard, Mare Island, Calif., died March 5 at his home in Lake Wales, Fla. He was the author of many technical papers presented at AFS Conventions and was active in the Northern California Chapter.

**William C. Baud,** plant superintendent, Mechanical Foundry Div., Food Machinery Co., Los Angeles, died March 17 at Downey, Calif. He was Chairman of the AFS Southern California Chapter 1955-56.

**C. Kenneth Flagg,** superintendent, Kincaid Osburn Electric Steel Co., San Antonio, Texas, has died.

**A. J. Dempsey,** vice-president, Crucible Steel Casting Corp., Milwaukee, died recently.

**E. O. Fattmann,** sales representative, General Refractories Co., St. Louis, has died.

# THE PERPLEXING PROBLEM OF HARD SPOTS

## Another costly mystery solved–by the man from Kaiser Aluminum

THE PUZZLING FACTS. An aluminum foundryman recently made a disturbing discovery: his castings contained many inclusions and hard spots. These made the castings very unsatisfactory. In addition, they were difficult to machine–and caused excessive wearing of tool bits.

HOW THE CASE WAS SOLVED. It was a frustrating problem. But the man from Kaiser Aluminum found the fault: ineffective fluxing and degassing techniques were being employed. When these were corrected, the hard spots disappeared and production returned to normal.

WE LOVE A MYSTERY. This is one of many actual cases solved by Kaiser Aluminum working with a customer. Perhaps *you* have a mystery one of our technical engineers might help solve? He's ready to give you expert advice on any casting problem–including mold and die design, alloy selection, heat treatment, finishing, fluxing, metal transfer.

FULL ALLOY AVAILABILITIES. Kaiser Aluminum can supply you *fast* with a wide selection of casting alloys to suit any engineering requirement–from general purpose, low stressed alloys to high purity alloys having good properties at elevated temperatures.

FOR PIG AND INGOT with a free sleuthing bonus, call your nearest Kaiser Aluminum sales office now. Or write: Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Illinois.

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THE BRIGHT STAR OF METALS

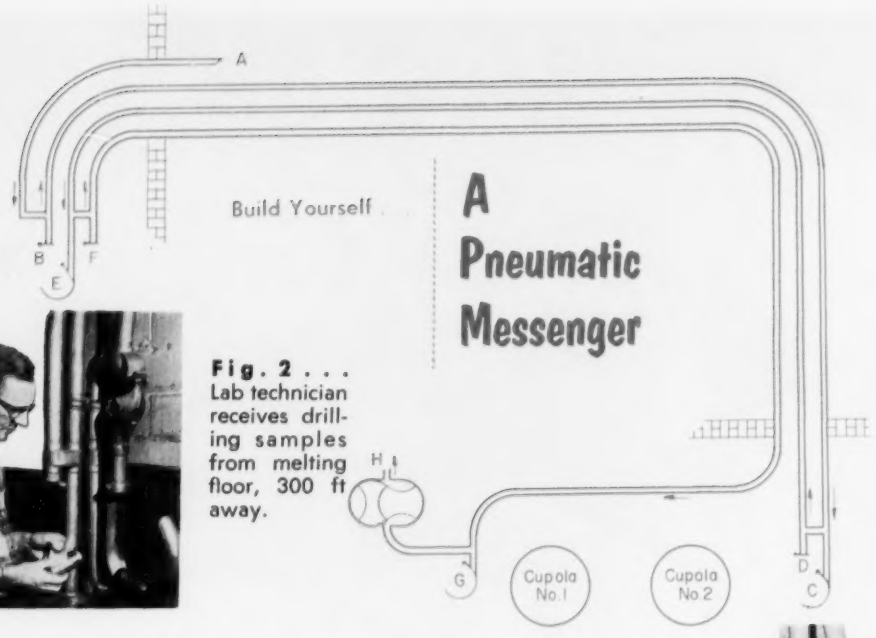
See "MAVERICK" • Sunday Evenings, ABC-TV Network • Consult your local TV listing

Circle No. 172, Page 141-142

Build Yourself

# A Pneumatic Messenger

**Fig. 2 . . .** Lab technician receives drillings samples from melting floor, 300 ft away.




*By*
KEITH L. POTTER
*Modern Castings*

**Fig. 1 . . .** Sample cupola drillings begin 7-second journey to laboratory.

Golden Foundry, Columbus, Ind., has reduced the time needed for analysis of cupola drillings approximately 65 per cent. The speed-up was made possible by a "did it themselves" delivery system which speeds samples through a two-inch pneumatic tube a distance of 300 ft to the second-floor chemistry laboratory—in just seven seconds.

Golden Foundry was fortunate in being able to purchase a quantity of used pneumatic conveyor tubing, elbows, discharge and entry gates and cartridges from a firm engaged in dismantling and removing this equipment from an old building. Cartridges were the type formerly used in department stores to transmit sales slips, currency and change from counter to cashier. However, any smooth, thin-wall tubing having a two-inch diameter could probably be adopted to do the job. Any competent sheet metal worker can make suitable cartridges.

The blower (used in this instance as an exhauster) had been unused for years. A blower speed of around 850 rpm is obtained from a one-hp, 1800-rpm electric motor salvaged from a discarded portable belt conveyor.

The sample drilling station is in chartroom No. 2 (Fig. 1). A worker puts drillings into a small envelope and inserts it in a cartridge which he introduces into the pneumatic conveyor through a hinged door or gate (D).

Seven seconds later a technician in the chemistry laboratory, 300 conveyor-feet from the drilling station and 20 feet higher in elevation, removes the sample at E (Fig. 2) and starts routine analysis.

Three to 20 minutes later, depending on total requirements, the chemist completes his analysis. He encloses the written report in one of the cartridges and inserts it at either B or F, depending upon which cupola is in operation that day. The cartridge then reaches the melting floor at either C or G.

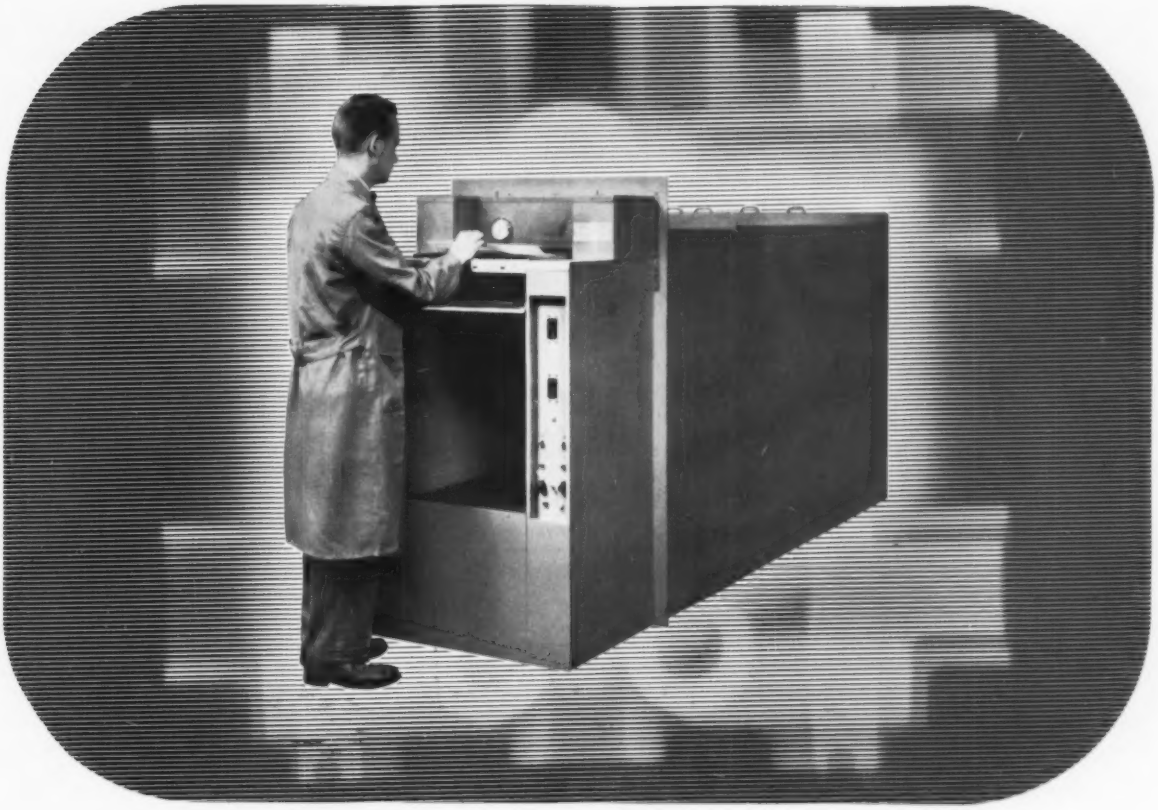
Originally, air entered the pneumatic conveyor system from the chemical laboratory, B. In the winter this warm air with its higher water vapor content was chilled when drawn through the outside pipe, (B, E, F to G, D, C), presenting problems in water condensation.

Extending the air-intake pipe outside the lab building, B to A, solved the problem of temperature drop and accompanying condensation. A tee at discharge point G connects the blower intake to the conveyor tubing. This arrangement induces negative pressure throughout the tubing system starting at entry A.

Before the pneumatic conveyor was installed, one man spent half his working hours carrying samples at 15-minute intervals from the melting floor to the laboratory. Moreover, errors incurred in telephone communication of lab results to a moderately noisy melting floor location were not uncommon.

Golden Foundry officials estimate that original cost of their pneumatic conveying system is returned several times a year in labor savings. Maintenance has been negligible, and cost of operation is limited to operating the one-hp motor.

Of even greater importance, closer metallurgical control results from reducing the time lag between sampling and receipt of results.



## 13-minute industrial x-ray film processing

# New Kodak Industrial X-Omat Processor can save you time and money

Kodak offers you automation in film processing—radiographs of uniform high quality, dry and ready to read in 13 minutes.

Film hangers are eliminated. Exposed films are merely removed from the film exposure holders and fed directly into the processor. Kodak Industrial X-ray Film, Type AA and Type M—sheet films or continuous lengths from 70mm to 17 inches wide—go through the system at 38 inches per minute. *And* only 22 inches of the unit's 10-foot 10-inch length need extend into the darkroom itself.

The Kodak X-Omat Processing System saves time and cuts costs. You'll want the complete story.

**Send for the folder that gives all the details.**

X-ray Division—EASTMAN KODAK COMPANY—Rochester 4, N.Y.

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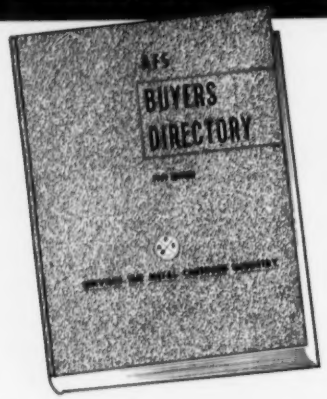
Circle No. 174, Page 141-142

# AFS BUYERS DIRECTORY

*(First issue Sept. 15, 1959)*

***The only complete Buyers Directory serving the Metal Casting Industry***

**ACT NOW**
*Advertising deadline July 1*

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- . . . **Because these are the men with the buying influence—who spend an estimated $2½ billion dollars annually.**

***BE THERE WHEN THEY MAKE THEIR BUYING DECISIONS!***

**The AFS Buyers Directory will have two years of life. This is your last chance to advertise until 1961! Reserve space now.**

# AFS BUYERS DIRECTORY

**published by**
**American Foundrymen's Society**
**Golf and Wolf Roads**
**Des Plaines, Illinois**


**Build an idea-file for improvement and profit. The post-free cards *on the last page* will bring more information . . .**

# for the asking

**Radiograph processing** . . . of medical x-ray film is subject of bulletin describing new processing unit. *Eastman Kodak Co.*
**Circle No. 37, Page 141-142**

**Electronic computer** . . . and allied equipment was put into service by foundry. Case history offered to you for the asking. *Remington Rand Div., Sperry Rand Corp.*
**Circle No. 38, Page 141-142**

**Gating and risering** . . . refractory folder includes complete file of company's strainer cores. *Louthan Mfg. Co.*
**Circle No. 39, Page 141-142**

**Coreblower** . . . with automatic push-button control fully explained in bulletin No. 5016. *Beardsley & Piper Div., Pettibone Mulliken Corp.*
**Circle No. 40, Page 141-142**

**Foundry sand** . . . brochure discusses production facilities for 24 grades of sand. *Wedron Silica Co.*
**Circle No. 41, Page 141-142**

**Laboratory safety** . . . involving use of chemicals is one of many articles in company's publication. *Union Carbide Chemicals Co., Div. Union Carbide Corp.*
**Circle No. 42, Page 141-142**

**Vibrating screens** . . . booklet No. 2777, 48 pp, describes line which manufacturer claims is largest in world. *Link-Belt Co.*
**Circle No. 43, Page 141-142**

**Pneumatic sand scrubber** . . . covered in new bulletin, yours when you circle number below on Reader Service card, last page.
**Circle No. 44, Page 141-142**

**Training courses** . . . pertinent to every type of metalcasting work are offered by the AFS Training and Research Institute. For free brochure covering all courses offered, circle number below on Reader Service card, last page. *American Foundrymen's Society.*
**Circle No. 45, Page 141-142**

**Corrosion data** . . . on alloys produced by this company offered in 40-p booklet showing penetration rates for the alloys in 250 corrosives. *Haynes Stellite Co.*
**Circle No. 46, Page 141-142**

**Floating zone method** . . . of metal refining and crystal growing reportedly produces ultra high purity semi-conductor materials and metals. Company publication includes this and other articles on high frequency induction heating. *Lepel High Frequency Laboratories.*
**Circle No. 47, Page 141-142**

**Automation** . . . enables Michigan foundry to pour 150 automobile V-8 engine blocks per hour. Use the circle number below to request free tear sheet from MODERN CASTINGS. *American Foundrymen's Society.*
**Circle No. 48, Page 141-142**

**Shell molding lubricants** . . . described in bulletin covering both hot coating and cold coating methods. *Nopco Chemical Co.*
**Circle No. 49, Page 141-142**

**Light reflectors** . . . said to control artificial light with maximum efficiency featured in illustrated booklet detailing finishes, service, specifications and performance of aluminum reflectors. *Aluminum Co. of America.*
**Circle No. 50, Page 141-142**

**Metalcasting technology** . . . experts have written many books and manuals which are available through AFS. A complete, classified list is yours when you use the circle number below. *American Foundrymen's Society.*
**Circle No. 51, Page 141-142**

**Cobalt** . . . discussed in quarterly publication devoted to cobalt and its uses. Issue No. 1, includes abstracts of recent technical articles dealing with cobalt. *Centre D'Information du Cobalt, Brussels.*
**Circle No. 52, Page 141-142**

**Cost control** . . . pointers are listed and discussed in bulletin. *Small Business Administration.*
**Circle No. 53, Page 141-142**

**Clamping tools** . . . catalog acquaints reader with application, construction, specification and price data on over 400 items. *Wilton Tool Mfg. Co.*
**Circle No. 54, Page 141-142**

**Iron foundry alloys** . . . covered in brochure detailing composition, uses and advantages of 31 alloys. *Vanadium Corp. of America.*
**Circle No. 55, Page 141-142**

**Material handling** . . . basic concepts are outlined in revised publication, 16

*Continued on page 124*

## "OLIVER" No. 12 Hand Planer and Jointer has tilting front table for planing draft

Front table tilts sideways up to 5 degrees, enabling the pattern maker to obtain the draft on every straight piece of wood that passes through his hand. Available in 20", 24" or 30" width planing capacity. Heavy bed, mounted on two cabinet columns, dissipates all vibration and allows maximum footroom for operator. Send for free folder giving technical details.

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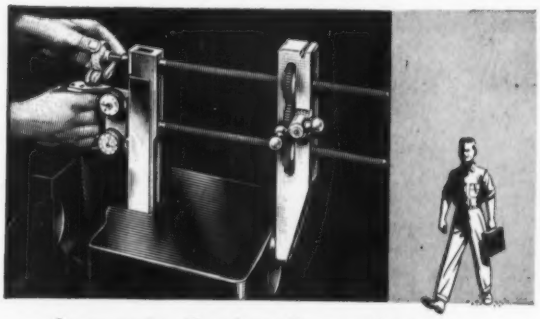
Circle No. 175, Page 141-142



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Perfect for on-the-job production testing of both parts and stock materials, because it weighs just 3 lbs. 6 oz., gives accurate readings at any angle. Requires no set-up time, eliminates need for carrying large pieces to test bench or cutting test samples. Uses standard indentors and loads so no scale conversions are necessary. Rockwell scales A, B, C, D, E, F, G, H and K available as standard.
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A DIVISION OF
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2. Have him supply you with our simple-to-use Abrasive Cost Record form. There's no charge for these.
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Circle No. 177, Page 141-142

## for the asking

*Continued from page 140*

pp. *Material Handling Institute, Inc., Educational Div.*
**Circle No. 56, Page 141-142**

**Ancient casting** . . . of India. Iron pillar with interesting history and significant composition discussed in free tear sheet from MODERN CASTINGS. Use the Reader Service card, last page. *American Foundrymen's Society.*
**Circle No. 57, Page 141-142**

**Index** . . . to 1958 MODERN CASTINGS. Lists the subjects, titles and the authors of all important information published during last year. *American Foundrymen's Society.*
**Circle No. 58, Page 141-142**

**Shaw Process** . . . explained in bulletin which illustrates applications of precision casting technique. Circle the number below on Reader Service card, last page, to get your copy. *Shaw Process Development Corp.*
**Circle No. 59, Page 141-142**

**Ductile iron** . . . alloys described and specifications listed in bulletin. *Vanadium Corp. of America.*
**Circle No. 60, Page 141-142**

**Charging equipment** . . . booklet, 28 pp, details complete mechanical charging equipment systems for foundries. Contains full color product and application photographs. *Whiting Corp.*
**Circle No. 61, Page 141-142**

**Management aids** . . . published by the United States Government offer valuable assistance to those in responsible positions in small business. Following is a list of bulletins available when you circle the appropriate number on the Reader Service card, last page.

How to Analyze Your Own Business
**Circle No. 62, Page 141-142**

Developing sound production standards
**Circle No. 63, Page 141-142**

Office Mechanization for Small Industry
**Circle No. 64, Page 141-142**

Term Loans in Small Business Financing
**Circle No. 65, Page 141-142**

Economics in Lubrication
**Circle No. 66, Page 141-142**

Making a Marketing Survey
**Circle No. 67, Page 141-142**

Care of Hydraulic Systems
**Circle No. 68, Page 141-142**

Streamlining Office Systems in Small Business
**Circle No. 69, Page 141-142**

**Tape recordings** . . . of technical talks on many facets of the metalcastings industry are available from AFS. Circle number below for complete listing. *American Foundrymen's Society.*
**Circle No. 70, Page 141-142**

## free reprints

■ **The following reprints of feature articles which appeared in MODERN CASTINGS are available to you free of charge. Use the Reader Service card, last page.**

**Molybdenum** . . . effect on gray iron elevated temperature properties is subject of free reprint from MODERN CASTINGS. *American Foundrymen's Society.*
**Circle No. 71, Page 141-142**

**Calcium carbide** . . . injection process discussed as it relates to the foundry industry in article reprinted from MODERN CASTINGS. *American Foundrymen's Society.*
**Circle No. 72, Page 141-142**

**Centrifugal pumps** . . . in sand reclamation system help minimize maintenance costs. Read about it in your free MODERN CASTINGS reprint—yours when you circle number below on the Reader Service card, last page. *American Foundrymen's Society.*
**Circle No. 73, Page 141-142**

**Automatic moisture control** . . . of sand discussed in reprint from MODERN CASTINGS. *American Foundrymen's Society.*
**Circle No. 74, Page 141-142**


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**GUARANTEED Brass, Bronze and ALUMINUM INGOT to your specifications IMPROVED WITH FACTOR "X"!**

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**Circle No. 178, Page 141-142**

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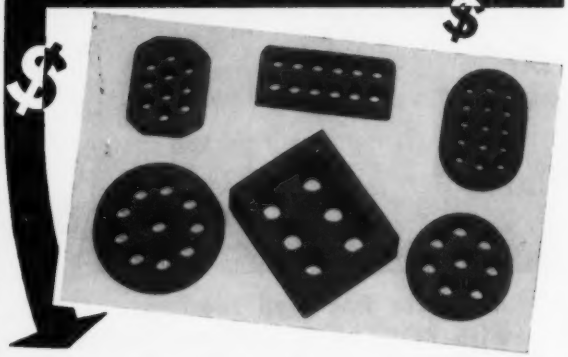

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**Circle No. 179, Page 141-142**

*Set your own pace to modernization---*

# mechanize step by step

## *with LINK-BELT equipment*

SMALL or large foundries can modernize systematically with the help of Link-Belt planning . . . perfected through 50 years of serving foundries. Industry's broadest line of conveyors and preparation machinery allows you to add equipment where it's needed most . . . *piece by piece at your own pace.*

Start anywhere! Whether it's the handling of sand, cores, molds, castings . . . or a complete system—Link-Belt will furnish and install equipment that results in lower costs, more efficient operation, better working conditions.

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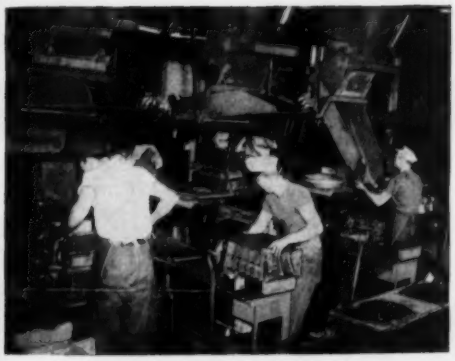
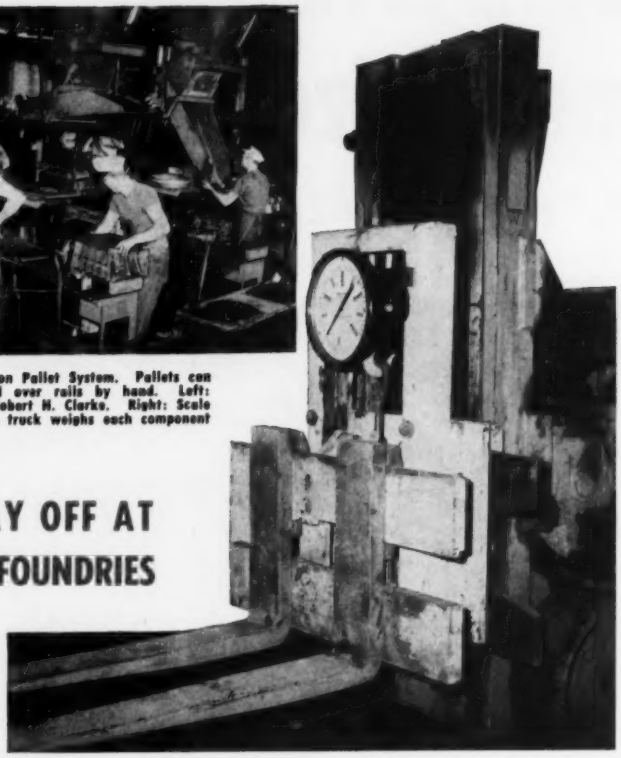
Circle No. 180, Page 141-142



View of Gray Iron Pallet System. Pallets can be easily moved over rails by hand. Left: Plant Engineer Robert H. Clarke. Right: Scale mounted on fork truck weighs each component of charge.



# ENGINEERING APPLICATIONS PAY OFF AT DALTON FOUNDRIES

**INCREASED EFFICIENCY**

To obtain faster, more efficient, production in the company's gray iron foundry, Robert H. Clarke, Plant Engineer at Dalton Foundries, Inc., Warsaw, Indiana, designed a pallet system. This flexible system allows molders to work two hours before pouring needs to begin. Cooling time can be varied to suit the job and pallets can be easily moved over rails by hand. No bottom boards are used and the handling formerly required to bring them back to the molders has been eliminated. The pallet system provides flexibility for both production and jobbing type work.

**BETTER CONTROL**

When bond and water are added to sand during mulling, the bond must be thoroughly combined with water to be effective. Plant Engineer Clarke designed a system to pre-mix water and bond, and pump the mixture into a storage tank where it is stirred continually. From the storage tank, small amounts of the mixture are metered into a tank by a timer. Compressed air then blows this metered amount into the muller at the correct time. This system has resulted in better control of sand, faster mulling cycles, and easier handling of materials.

**LOWER COST**

At the Dalton Foundries the old wheelbarrow method used to charge the cupola required seven men. Clarke designed a scale which could be mounted on the front of a fork truck to weigh each component of the charge as it was loaded into a drop-bottom tub on the truck. After it is loaded, the fork truck delivers the material to the charging bucket. This simple, and inexpensive engineering change reduced the labor requirement to three men instead of the seven previously required.

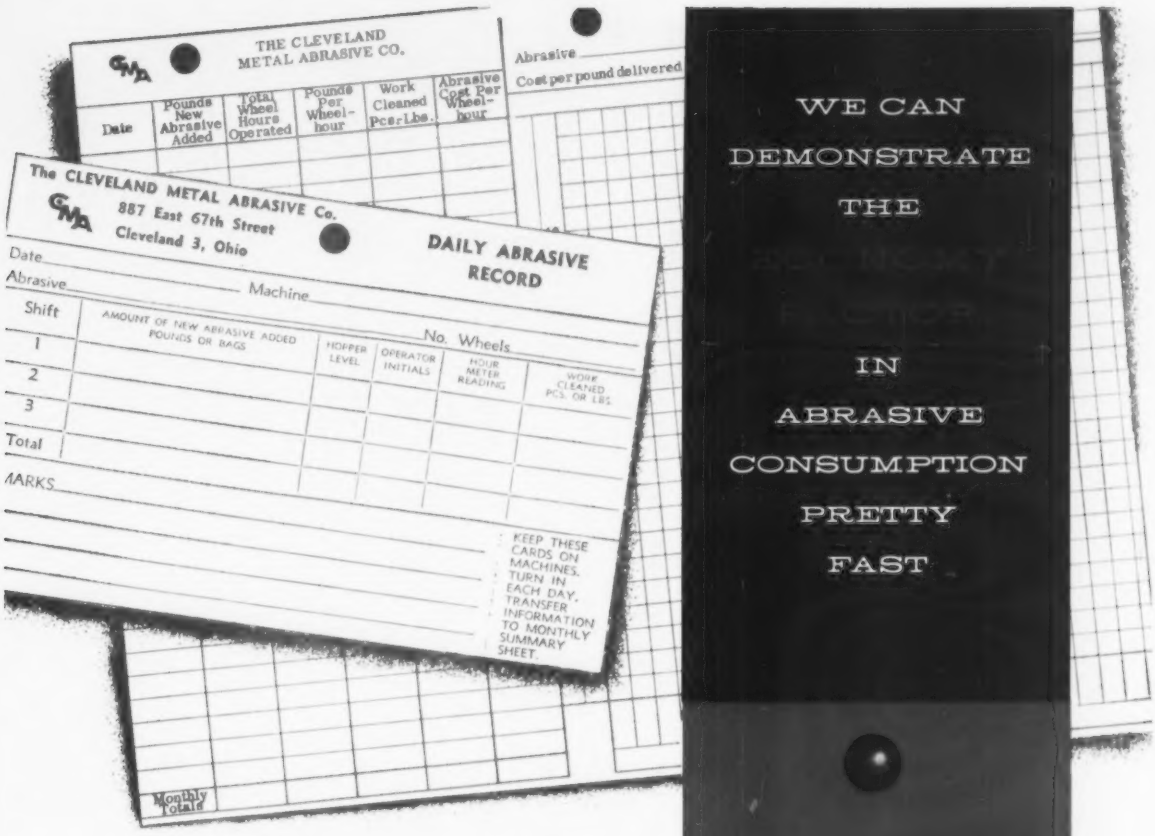
**You can help create a source of engineering talent for the foundry industry by participating in the FEF program as a contributing member.**

## Foundry Educational Foundation

1138 TERMINAL TOWER BUILDING • CLEVELAND 13, OHIO

Space contributed by **Modern Castings** as another service to the metal castings industry.

Circle No. 181, Page 141-142




Simple arithmetic and common sense establish the pattern. It's simply a matter of making high quality, *long-lasting* abrasives. The less you use, the more money you save. Take Cleveland High-strength "A" iron shot and grit. Greater abrasive life and decreased machine maintenance costs offset any minor increase in initial costs. Bargain prices cut no ice . . . ever.

Prove to yourself the savings you get from this, and other, Cleveland Metal Abrasives. Write—and ask for our new abrasive cost system, which our engineers can quickly establish for each machine, at no cost to you.

Also write us today for more information, together with new catalog No. 159, or call our nearest representative.

**CLEVELAND is the name and the place for PERSUASIVE ABRASIVES**

| | | |
|---|---|---|
| 1. Realsteel Shot and Grit | 2. Pearlitic Malleable | 3. Normalized |
| 4. "A" Iron | 5. Hi-Strength "B" | 6. Chilled Iron |
| | | 7. Cut Wire |

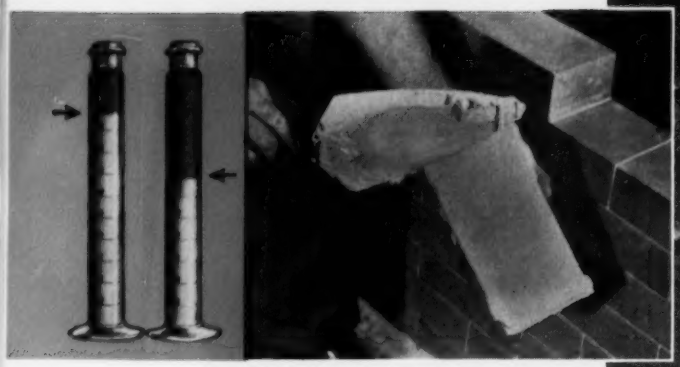
**the CLEVELAND metal abrasive company**

GENERAL OFFICE: 888 East 67th Street • Cleveland 3, Ohio • PLANTS AT Howell, Michigan; Toledo; Cleveland

*World's Largest Production Capacity*

Teletype: CV 901

Circle No. 155, Page 141-142



1. Settling test (as shown) demonstrates that ANKORITE 65 remains longer in suspension, a valuable characteristic of a hot-setting mortar. ANKORITE 65 in the graduate on the left, shows no settling, while ordinary mortar in the other tube has settled considerably in the same time.
2. ANKORITE 65 spreads smoothly and well, making uniform joints of the thickness desired.
3. View of malleable furnace wall of high-quality super-duty fireclay brick laid with ANKORITE 65. The unusual resistance of this mortar to severe slagging action and erosion is illustrated by the joints which extend beyond the brick.

# Harbison-Walker Ankorite 65

## The new WIDELY-USED bonding mortar • more refractory • more workable • more durable • for super-duty and high-alumina brick

The protruding mortar joints of the furnace wall in the photograph illustrate the exceptional durability of ANKORITE 65. This shows a portion of a malleable furnace wall of high-quality super-duty fireclay brick laid with this mortar. As is obvious, after the normal period of service, the mortar has been less eroded than the brick.

ANKORITE 65 is a high-alumina heat-setting mortar which develops a strong ceramic bond of high resistance to slag corrosion and to severe erosion of metal and slag at high temperatures.

ANKORITE 65 is used with splendid results for laying bottom blocks and linings of blast furnaces up to the mantle. It is particularly suited for laying various alumina-silica brick linings of transfer ladles, for electric furnace roofs, and for malleable and air furnace side walls and bottoms. The good workability of this mortar lends itself to easy trowelling or dipping in securing strong impervious joints. In some applications it is used with benefit for protective coatings by spraying or brushing.

The Garber Research Center

*Leadership in refractories through constant research*

**Harbison-Walker Refractories Company**

AND SUBSIDIARIES *World's Most Complete Refractories Service*

GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

Circle No. 183, Page 141-142

# VOLCLAY BENTONITE

## NEWSLETTER No. 62

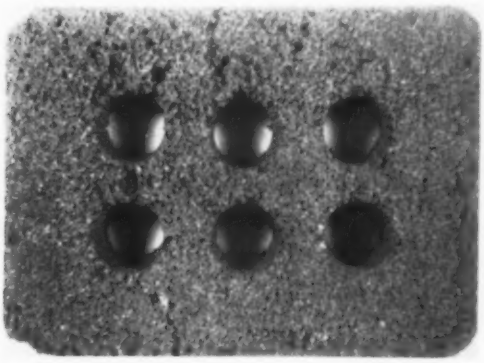
REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

# A Source Of Inclusions

**The illustration shows the puzzlement** of foundry personnel in attempting to properly identify "dirt".

It is known that "dirt" is most generally not associated with the actual source of an inclusion.

**One source of inclusions may be from strainer cores.** Strainer cores are placed in a gating system to eliminate slag, sand and "dirt".



**One must be critical of poorly prepared strainer cores. Poor strainer cores are dangerous to foundry practice** and careful control should be established in their manufacture.

**A poor strainer core** may be the direct cause of inclusions. The photo shows clearly that this strainer core could erode easily upon pressure of hot flowing metal.

**This strainer core has been rammed too softly.** There are too many voids for metal to seek. The strainer core is entirely too brittle to withstand constant ferro-static pressure.

**ARE YOU ON OUR MAILING LIST**
**TO RECEIVE EACH MONTH THE LATEST FOUNDRY DATA ?**

## AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • PRODUCERS OF VOLCLAY AND PANTHER CREEK BENTONITE

Circle No. 184, Page 141-142

# foundry trade news

**NATIONAL CASTINGS COUNCIL . .** has elected the following to office: President, R. L. Gilmore, Superior Steel & Malleable Castings Co., Benton Harbor, Mich.; Vice-President, A. M. Nutter, E. L. LeBaron Foundry Co., Brockton, Mass.; Secretary, F. G. Steinebach, Penton Publishing Co., Cleveland; Treasurer, F. R. Fleig, Smith Manufacturing Co., Cleveland.

**AMERICAN SOCIETY FOR METALS . .** has named A. R. Putnam as managing director. The post is a new one created following the death of W. H. Eisenman, executive head of the society for 40 years. Putman was previously assistant executive secretary of the American Society of Tool Engineers.

**DUCTILE IRON SOCIETY . .** held its first election of officers in Chicago during the recent AFS Castings Congress. The officers are: President, R. S. Thompson, H. P. Deuscher Co., Hamilton,

**R. S. Thompson**

Ohio; Vice-President, William Beatty, Morris Bean Co., Yellow Springs, Ohio; Secretary-Treasurer, R. K. Guise, Kuhn's Bros. Co., Dayton, Ohio; Executive Secretary, J. H. Lansing.

**BRASS & BRONZE INGOT INSTITUTE . .** has published results of a research program sponsored by the organization which investigated 16 mechanical and physical properties of three standard copper-base alloys.

**SOCIETY OF DIE CASTING ENGINEERS . .** has elected the following to office: President, D. L. Rockwell, Clifford-Rockwell Co., Detroit; Vice-President, E. R. Mason, American Mold Engineering Co., Charlevoix, Mich., Secretary, E. R. Mason; Treasurer, M. R. Tenenbaum, Lester-Phoenix, Inc., Detroit.

**STEEL FOUNDERS' SOCIETY OF AMERICA . .** has elected D. L. Hall,

**D. L. Hall**

Oklahoma Steel Castings Co., Tulsa, to a three-year term as national technical and operating chairman.

**GRAY IRON FOUNDERS' SOCIETY . .** has announced that the deadline for entries in the 1959 casting design contest is June 30.

**INVESTMENT CASTING INSTITUTE . .** sponsored a successful Design and Application Clinic at Santa Monica, Calif., in cooperation with the California Investment Casters Society. Over 200 design engineers, metallurgists, purchasing executives and other casting users' representatives attended the program.

**MALLEABLE FOUNDERS SOCIETY . .** has announced the following winners in the Annual Safety Self-Improvement Contest: Dalton Foundries, Inc., Northern Malleable Iron Co., Erie Malleable Iron Co. and Central Foundry Division, General Motors Corp.

**CAST BRONZE BEARING INSTITUTE . .** is planning to publish a manual containing the latest theoretical and experimental sleeve bearing design information. Data in the manual will be developed through a project sponsored by the group at the Franklin Institute.

**International Harvester Co. . .** will discontinue production of farm implements at its McCormick Works in Chicago. Production of malleable castings will be shifted to Waukesha, Wis., and some foundry operations requiring about 500 employees will be continued after implement production stops.

**Ohio Ferro-Alloys Corp. . .** has placed new plant at Powhatan Point, Ohio, in full production. Major production of the plant is silicon metal for the aluminum and chemical industries.

**F. E. (North America) Ltd. . . .** Toronto, Can., has announced United States representatives for their foundry equipment:

Snyder Foundry Supply Co., Los Angeles; representatives for California, Nevada, Utah, New Mexico and Arizona.

C. W. Ammen, Gulfport, Miss.; Texas, Louisiana, Mississippi, Alabama, Mexico and Columbia.

Foundry Supply Co., Minneapolis: Saskatchewan, Manitoba, North and South Dakota, Nebraska, Iowa and Minnesota.

LaGrand Industrial Supply Co., Portland, Ore.; Oregon.

**Superior Foundry, Inc. . . .** Walter L. Seelbach, president of the Cleveland firm, was reported in the *Cleveland News* as believing that the metalcasting industry may do as much as 20 per cent more business in 1959 than in 1958. Business of Superior Foundry is expected to improve to an even greater extent due to purchase of the assets, good will and trade name of Allyne-Ryan Foundry Co. in October 1958.

**Terminal City Iron Works Ltd. . .** sponsored the exhibit pictured here at the

Pacific National Exhibition. The Terminal City plant is in Vancouver, B. C.

**American Steel Foundries . .** has purchased South Bend Lathe Works, South Bend, Ind., subject to agreement of South Bend stockholders. A.S.F. has also announced sale of its Verona, Pa., plant to Specialty Steel Products, Inc.

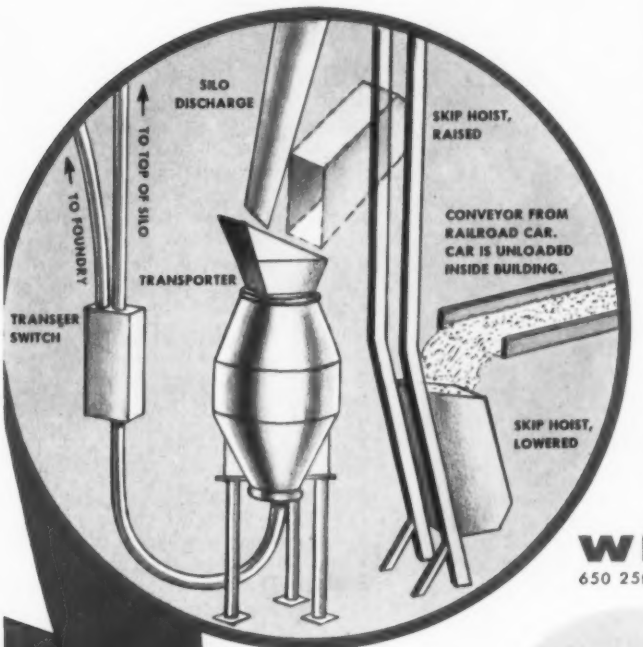
## It loads silo from car! It delivers sand to foundry area!

# WHIRL-AIR-FLOW SYSTEM SPEEDS SAND HANDLING FOR AMERICAN HOIST & DERRICK COMPANY

Two jobs in one . . . that's the double-duty performance of this Whirl-Air-Flow automatic sand handling system at the American Hoist and Derrick Co. plant in St. Paul. A 70-ton load of silica sand is transferred from railroad car to silo in less than one hour—through a completely automatic cycle. Sand from the 350-ton capacity silo is quickly delivered in desired quantities to the foundry area by the Whirl-Air-Flow transporter.

Operating now for three years, the system is pronounced "completely satisfactory" by American Hoist. Along with its highly efficient unloading, storing and delivery, the system is praised for its self-cleaning ability and practically maintenance-free operation.

**TELL US YOUR SAND HANDLING PROBLEM!** Let us show you how Whirl-Air-Flow pneumatic conveyor systems, engineered to your individual requirements, can boost your production while giving you appreciable cost savings. Your inquiry promptly acknowledged!




**WHIRL-AIR-FLOW**

650 25th Avenue S. E., Minneapolis 14, Minn. • FEderal 9-0231

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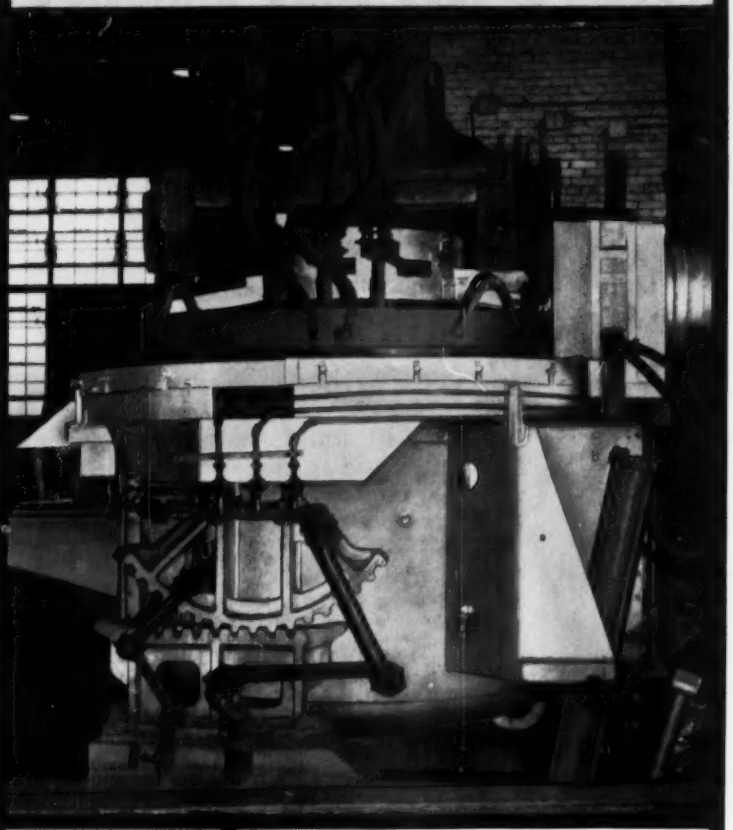
CONTROL ELECTRIC FURNACE FUMES



Pangborn offers a new concept in electric furnace exhaust hoods!

After years of development, Pangborn now offers effective control of smoke, fumes and dust from electric melting furnaces with minimum interference to furnace operations and maintenance. The hood design is based on the fundamental dust control principle of confining and capturing fumes and dust immediately adjacent the source. Effective control is secured with substantially reduced exhaust air volumes.

The Pangborn Exhaust Hood reduces the weight carried by the furnace roof; reduces hood areas subject to high temperatures; reduces electrode travel limitations and is applicable to top and side charge furnaces of all types and sizes.

With the exhaust hood connected to an efficient Pangborn Cloth Bag Collector, compliance with the most rigid air pollution control regulations is assured. For information call the Pangborn man in your area or write: PANGBORN CORP., 1300 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

Pangborn CONTROLS DUST

Circle No. 187, Page 141-142


# Modernize Your

*By* Alfred B. Steck, *Metallurgical Associates, Inc. Boston*


■ This talk is aimed at increasing profits through reducing manufacturing costs and increasing sales through the utilization of new developments in the foundry industry.

Let's first look at current cupola practice in the iron foundry. Whether a cupola practice is acid, basic or neutral depends on the slag materials. Acid slags are made up of mostly sand; basic slags, of lime; and neutral slags, of equal parts of sand and lime. The advantages of basic over acid are: lower sulfur, higher temperatures and high carbon level with 100 per cent steel scrap charge. To be compatible with the slag, the lining of the cupola must be either acid, basic or neutral.

The basic-operated cupola produces low sulfur iron which is practically a must for making small ductile iron castings. The higher the sulfur level, the more magnesium needed to bring the sulfur level down to where spheroids are formed rather than flake graphite.

There is an increasing trend towards using water-cooled cupolas and melting against the shell without a lining. The cupola can then be operated acid, basic or neutral. Some shops operate the cupola acid for gray iron and then change to basic during the day for ductile iron. The cost of water for cooling should be compared to the reduced refractory costs. A large cupola needs about 60 gallons per min of cooling water.

Compare this with refractory costs of about 15 cents per ton of melt. The water-cooled cupola has the disadvantage of producing molten metal with a lower temperature at the spout. This can be overcome by utilizing a hot blast.

The larger foundries are installing water-cooled, hot blast cupolas because of the versatility and savings resulting from decreased coke consumption, decreased refractory costs, less silicon loss, decreased pig iron consumption, hotter metal and good sulfur control.

Many non-ferrous foundries are producing cores by the shell technique. For an initial machine invest-

ment of about $2000, shell cores for production runs can be made economically. Good shakeout, plenty of venting, long storage life, no oven needed,—all these decided advantages should be considered.

Many foundries will mix their core ingredients in the following order: sand, cereal, oil and water. One of the reasons for adding cereal is to provide green strength which results from the gelatin of cereal by water. The oil when added first waterproofs the cereal and prevents full gelatin of the cereal. Therefore add sand, cereal, water, mix, oil and mix. You will probably find that you need less oil for a given dry strength than previously.

$CO_2$ core making has found its place in the core room. To solve shakeout problems in iron and nonferrous foundries, foundry syrup or carbon material is used. Cores are being blown in all makes of blowers. For long runs of small castings with flat backs, it is well to consider blowing $CO_2$ cores for stack molding techniques.

A few foundries are putting cores and coreboxes under vacuum and then passing in $CO_2$ gas. This has resulted in gas economy.

In casting intricate passageways in aluminum castings, use is being made of copper tubing covered with woven fiber glass. The tubing is leached out of the casting during the cleaning operation.

In the iron foundry where penetration or burn on is encountered, a core insert or core facing of carbon sand has solved many problems. Carbon sand having low expansion and good stability to heat shock has proven itself as another tool for overcoming foundry defects.

The cold setting core binders have proven economical in applications where core making is intricate. The practice of blowing air into deep pockets of cold setting cores hastens the setting process.

A new type of core binder just recently introduced supposedly needs no baking. This is composed of urea resin, a catalyst and a green bond material.

Fine finishes are being obtained using bentone clay and oil bonding of green sand. The absence of water in the molding sand results in the excellent surface obtained on brass and bronze castings.

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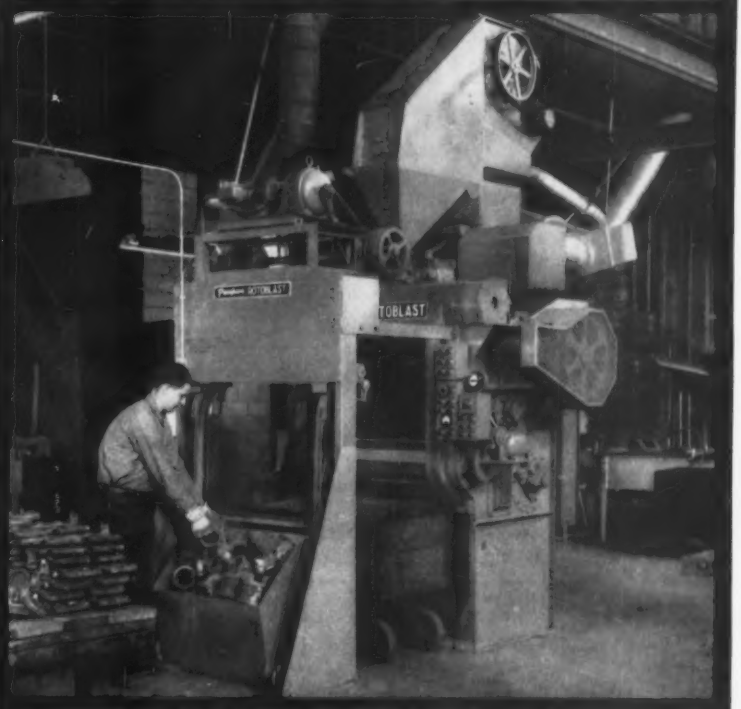
Editor's Note: *This article contains highlights excerpted from a talk by A. B. Steck presented at the 1958 AFS New England Regional Foundry Conference.*


ROTOBLAST CUTS CLEANING TIME 70%!



Pangborn Rotoblast reduces cleaning time from 15 minutes per load to 4½ minutes at Buckeye Iron & Brass

To reduce costs and still keep up production schedules, Buckeye Iron & Brass Works, Dayton, Ohio, replaced its centrifugal blast cleaning barrel (which is still in good operating condition) with an automated 6′ Pangborn Rotoblast Barrel. The result: cleaning time was cut from 15 minutes per load to 4½ minutes!

Through automation, the Rotoblast Barrel has also saved the company the cost of one full-time operator and has proved economical in terms of maintenance. In seven months, no repairs or replacements, other than vanes, have been necessary!

For full details on how Pangborn Rotoblast can save you money, write for Bulletin 706 to PANGBORN CORPORATION, 1300 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment—Rotoblast Steel Shot and Grit.*

Pangborn

CLEANS IT FAST WITH ROTOBLAST®

Circle No. 188, Page 141-142

# classified advertising

**For Sale, Help Wanted, Personals, Engineering Service, etc.,** set solid . . 25c per word, 30 words ($7.50) minimum, prepaid.

**Positions Wanted . .** 10c per word, 30 words ($3.00) minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 additional words.

**Display Classified . .** Based on per-column width, per inch . . 1-time, $18.00 6-time, $16.50 per insertion; 12-time, $15.00 per insertion; prepaid.

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**PLANT ENGINEERS**

Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent protograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**MANUFACTURERS' REPRESENTATIVES**

**A completely modern electric furnace foundry specializing in shell molding of high strength alloy iron castings and brass castings, desires to appoint MANUFACTURERS' REPRESENTATIVE in midwest and middle Atlantic states. Foundry can meet exacting specifications for physical properties, chemical analysis and microstructure. Men now calling on industrial accounts who require good production quantities of small castings are urged to write. List all qualifications, experience, current principals, etc. No objection to other non-conflicting foundry lines.**

**Box F-152, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**GOOD FOUNDRYMEN**

when you need SUPERVISORY or TECHNICAL men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL.

Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

**For action contact:**
**John Cope**
**DRAKE PERSONNELL, INC.**
**29 E. Madison St.**
**Chicago 2, Illinois**
**Financial 6-8700**

**AGENTS WANTED: Distributors or Manufacturer's Agents.** Several choice territories available to experienced foundry equipment salesmen or agencies interested in selling the world-famous **HANSBERG CORE SHOOTER.** Hansberg is the most successful core making machine of the last ten years and is better than competitively priced. More models than any other manufacturer. New bench and floor models include Semi- & Fully-Automatics. Combination Shooter-Gassers, Roll-Over-Strippers, Vacuum & Pressure $CO_2$ Gassers. **Write to HANSBERG SHOOTERS, INCORPORATED, P.O. Box 729, Evanston, Illinois.**

**FOUNDRY ENGINEER**

Ohio Manufacturer has an opening for an aggressive young man with ferrous foundry experience. Must be capable of analyzing, recording and solving problems involving scrap and process difficulties. Will have responsibility of recommending, carrying out and following through the changes required. Must have management potential. Furnish resumé stating education, experience and qualifications. Salary open.

**Box F-173, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**SALES REPRESENTATIVES**

Sales representation wanted for large Gray and Ductile Iron Foundry producing castings from 50 lbs. to 20 tons. Present sales organization being expanded. Territories opened in Ohio, Indiana, Illinois and Wisconsin. Send replies to:

**W. R. Neely**
**HANSELL-ELCOCK COMPANY**
**485 West 23rd Place**
**Chicago 16, Ill.**

**FOUNDRY ENGINEERING-GRADUATE**

Needed by corrosion-and-heat-resistant alloy foundry in northern N.J. Assume full responsibility process development and control. Write to Box F-170. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**INDUSTRIAL ENGINEER**

Experienced in foundry operations as well as general industry. Capable of taking over management of industrial engineering division of ACME member consulting firm. Degree necessary. Age 35-45. Send complete details and include recent photograph. All replies held in confidence. **Box F-135, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**FOUNDRY SALESMAN**

Wanted experienced Gray and Ductile Iron Salesman for the Chicago Territory. Castings from 50 lbs. to 20 tons. State salary required. All inquiries will be held in strict confidence. Telephone contact regarding this position can be made by calling **Bishop 7-4250** or send resumés to:

**W. R. Neely**
**HANSELL-ELCOCK COMPANY**
**485 West 23rd Place**
**Chicago 16, Illinois**

**FOUNDRY SUPERINTENDENT**

Wanted superintendent for small non-ferrous sand castings foundry in Rockford, Ill. area. Must have complete knowledge and experience in melting, gating and rigging of patterns. Sand control and sundry practices of a sand castings non-ferrous foundry. Give full qualifications and references. **Box F-156, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

Progressive and expanding company manufacturing specialized chemical products for the foundry industry invites applications for the following positions:

**RESEARCH ENGINEER FOR DEVELOPMENT DEPARTMENT**

Applicants should preferably be under 35, must have a good degree in Chemistry or Metallurgy and at least 5 years experience in research or industrial development work. Evidence of high ability in previous employment will be necessary and association with the foundry industry would be an advantage. The position is one of responsibility and the successful candidate must be capable of initiating and directing project activity, after a period of training.

**SPECIALIST ENGINEERS FOR TECHNICAL SERVICE DEPARTMENT**

(1) With exerience in the aluminum wrought alloy field. Knowledge of all phases of melting and casting billets and slabs of extrusion, rolling and forging is required.
(2) With experience in the foundry industry, particularly steel. Knowledge of solidification principles, gating and risering practices is required.

These two positions entail product application and development work in customers' plants, in support of field sales force, and extensive traveling is involved. Applicants should preferably be under 40 and have had successful sales experience in addition to wide technical knowledge. All positions offer excellent prospects for advancement and good starting salaries will be paid. Applicants should submit resume of qualifications and experience to:

**Foundry Services, Inc.**
**P. O. Box 8728**
**Cleveland 35, Ohio**

## Engineering Services

**FOUNDRY CONSULTANT—NONFERROUS** Sand—permanent mold—centrifugal permanent mold—and centrifuge permanent mold. High pressure castings a specialty. Address: ED JENKINS, 253—8th STREET, WEST PALM BEACH, FLORIDA. PHONE: TEMPLE 2-8685.

## Positions Wanted

**MANAGER** Progressive, practical and technically trained foundryman. 46 years of age. Well-versed in all phases of light to extra heavy ferrous and non-ferrous jobbing work. Cost and control minded. Very good labor relations. Now employed. **Box F-159, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**FOUNDRY SALES REPRESENTATION** Aggressive young man, 29, four years foundry sales experience, (grinding wheels) has opportunity to diversify. Would like to handle two or three additional foundry items, giving specific product concentration. Presently covering Southeast from Birmingham. Best references. **Box F-174, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**A Master Foundry Engineer** from an Indian University seeks employment. Young and energetic, with high academic career. Experience of one year in the field. Resumé upon request. **Box F-171, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

---

**MANAGER-ENGINEER** College graduate BSME, age 30, 9 years experience automotive and jobbing gray and ductile iron foundries, both in plant engineering and management. Presently employed as Foundry Manager. Will consider position in management, engineering, or engineering sales service organization. **Box F-175, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

## Wanted

**IDEAS WANTED**

We bring together creators of ideas and companies that can use them. Register your ideas with us. We will appraise it and try to sell it. Write for brochure.

**Box F-172, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**BACK VOLUMES** — Wanted to buy for cash of foundrymen, TRANSACTIONS American Foundrymen's Society and other scientific technical Journals, **A. S. ASHLEY 27 E. 21, N. Y. 10, N. Y.**

## For Sale

**CORE TESTING EQUIPMENT**

1—Universal Sand Strength Machine — serial No. 17629.
1—Tensile Core Strength Accessory.
1—Core Oven, 230 volts, 60 cycle, 24-in. I.D. — serial No. 22505.
1—Sand Rammer equipped with foot pedal — serial No. 22272.

Dietert equipment in excellent condition. Can be inspected.

**ARTHUR C. TRASK CO., 327 S. LaSalle St., Chicago 4, Illinois, Telephone WAbash 2-8900.**

**FOR SALE**

2 Lindberg Radiant Fired Electric Furnaces complete with controls, 440 V, 50 KW. Aluminum Match Plate Corp., 1500 Military Rd., Buffalo 17, N. Y.

**KUX DIE CASTING MACHINES**

Model K-5, 25-T. Locking Pressure new 1949, Weight 2200#, Extra equipment and brand new.

Model BA-12, 100 T Locking Pressure new 1948, Weight 8500#. Very reasonable. Excellent condition. Model #2-DC REED PRENTICE, 400 T. Locking Pressure, complete zinc new '51, running. Excellent.

**EVEREADY, Box 638 BPT., CONN.**
**EDison 4-9471-2**

**CUTS COST WITH ZIRCON SAND ! !**

Take advantage of its unique features — reduce cleaning costs by preventing "burn-in" of the sand, produce smoother surfaces for lower polishing and machining costs, etc. Hobart Brothers extracts zircon at their own Florida mine, so are able to offer you **Highest Quality** at **Attractive Prices.** Calcined, granular zircon sand is available for direct shipment from the mine. Write for additional information and prices—indicate approximate usage and quantities you are interested in. **HOBART BROTHERS CO., P.O. BOX 49, TROY, OHIO.**

**FOR SALE**

1—36 x 42 WHEELABRATOR in good condition
W/A TB Model Series 370, Serial #33512 with W. W. Sly Dust Collector.
133 bags, Serial #C-6693.
Price very reasonable.

**Box F-176, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

**FOUNDRY EQUIPMENT SALE**

★ **3 DETROIT ELEC. FURNACES**
★ **REFRACTORIES**
★ **TABOR MOULDING MACHINES**

In excellent operating condition to be sold far below original cost: 3 Det. Elec. Rocking Arc Furnaces complete with transformers and all controls, 300-500 lb. capacity ea.; Spare refractories available; 2 Tabor Moulding Machines; 1 Core Blower; 1 Rack Pig Molds; 2 Optical Pyrometers. Can be inspected beforehand. Call collect: SIDNEY DOREN, Owner

**ATLANTIC STEEL & TRADING CO.**
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**technical program**

*Continued from page 40*

speaker on the panel, outlined procedures for producing castings to close tolerances with the method. R. M. Ovestrud detailed the problems that air-set binders are intended to meet, and the controls necessary to make these binders work. . . . . **Sand Dinner: *Lets' Start Over* by J. B. Caine.** In presenting what he described as an "unfashionable story," Caine warned sand technologists that their art lacks any basis of quantitative fact. He noted that current sand technology is a system of evaluation, and not a system of control, because there exist no primary standards of comparison.

## MANAGEMENT DEVELOPMENT PAPERS

**So You Want to be a President** was the theme for four papers presented by four leading executives in the metalcasting industry. These papers were: ***Developing Technical Personnel* by J. H. Culling,** Carondelet Foundry Co.; ***Developing Operating Supervisory Personnel* by L. J. Woehlke,** Grede Foundries, Inc.; ***Developing Sales Personnel* by H. A. Forsberg,** Blaw-Knox Co.; and ***Developing Administrative Management* by B. L. Simpson,** National Engineering Co.

## PLANT AND PLANT EQUIPMENT PAPER

**The Foundry Plant Engineer, A Fifty Year Reminiscence by James Thomson.** The author reflected on his experiences as a pioneer plant engineer in the metalcastings industry.

## STEEL PAPERS

**Rapid Hydrogen Determination for Steel Foundry Control by C. C. Carson and B. J. Alperin.** The authors described a method for the determination of hydrogen in steel using the hot extraction technique and employing a Pirani gage for the analysis of the extracted gases for hydrogen by the thermal conductivity technique . . . . . **Interrelation Between Stress Concentration and Castability by J. B. Caine.** The author described the close relationship stress concentration, maximum load between shapes designed to minimum carrying ability and the castability of such shapes . . . . . **Design and Welding of Alloy Cast Steel for Steam Turbine Applications by L. W. Songer.** The author discussed the design, welding and quality control aspects of high quality castings relative to the need for more activity by foundries in these areas . . . . . **Deoxidation Defects in Steel Castings by R. A. Flinn and L. H. Van**

*Continued on page 140*


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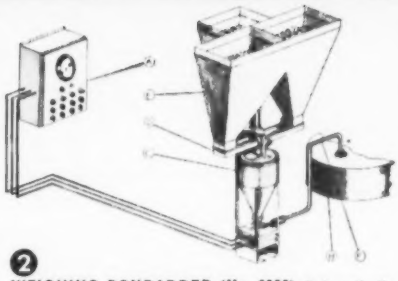

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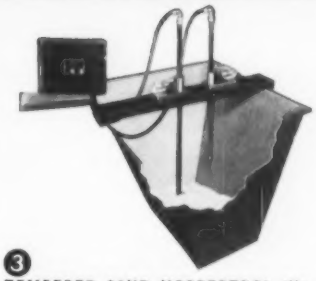

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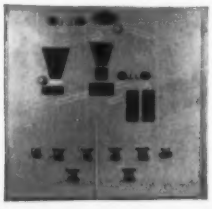

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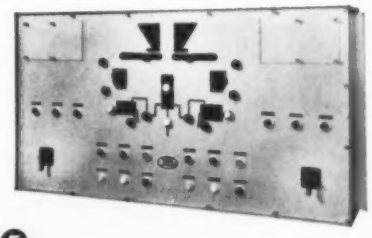

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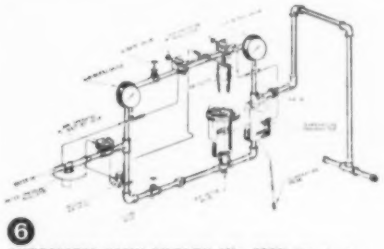

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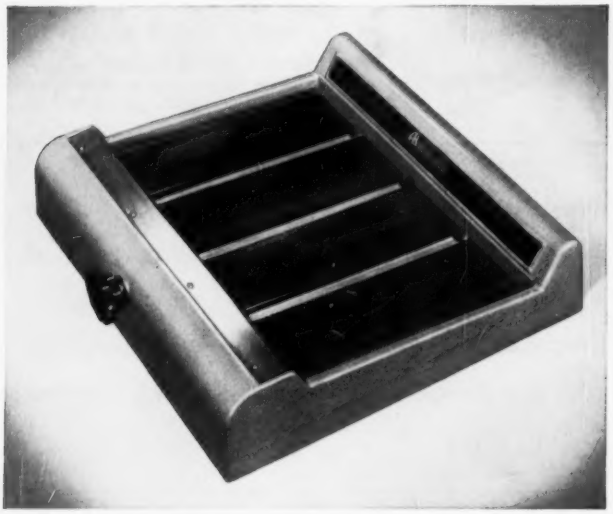

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Core Superintendent,
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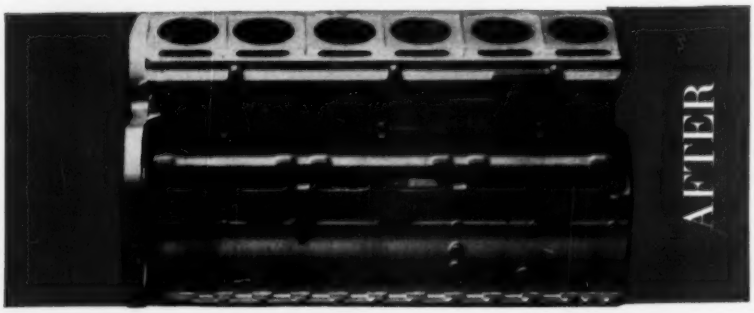


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## technical program

*Continued from page 136*

***Vlack.*** In this, the final report for the AFS Steel Division Research Committee, the authors described the nature of inclusions, the origin of inclusions and methods of eliminating this defect . . . . . **Reclaim Sodium Silicate Bonded Sand by G. C. Warneke.** The author described a study of the characteristics of reclaimed sodium silicated bonded sands. With the castings tested, the author found the $CO_2$ sand had greater dimensional stability than conventional green sand . . . . . **Cast and Wrought Alloy Steels by R. K. Buhr and W. A. Morgan.** The authors studied the cast and wrought properties at room and at elevated temperatures of four low alloy high strength steels. Castings were often found superior to wrought products, especially at elevated temperatures . . . . . **Requirements for Quality Steel Castings in the Aircraft Industry by Y. J. Elizondo.** The author reviewed the experiences of one aircraft company over the past three years to illustrated various reasons for success or failure of several steel casting designs . . . . . **Mn-V-Mo Age-Hardening Austenitic Steel by N. C. Howells and E. A. Lange.** The authors noted that successful casting of these new steels depends on special techniques. Melting, pouring, mold materials and heat treatment found to give best results was described . . . . . **The Significance of Reduced Phosphorus and Sulphur Content on the Ductility and Toughness of Cast Low Alloy Steels by John Zotos.** The author described a series of tests with alloys which showed improved properties when phosphorus and sulphur content was reduced . . . . . **A Method of Obtaining Both Castability and Maximum Field Service from Cast Products by J. W. Beckham.** The author described procedures for developing a design for a cast part which will combine good castability with equal stress distribution on the castings while it is in the field use . . . . . **Designing for Press-Forged Castings by P. Gouwens, T. Watmough and J. Berry.** The authors studied the improvement in mechanical properties obtained through combining the press forging and casting processes in the production of parts from three alloys: SAE 4340, 17-4PH and 347 stainless . . . . . **Foundry Designing for Steel Castings by A. B. Steck.** The author explained the latest techniques in controlling hot tear defects in relation to proper casting design . . . . . **Steel Luncheon: Vacuum Arc Melting by S. J. Noesen.** Mr. Noesen traced the development of the process from its early laboratory stages to commercial production.

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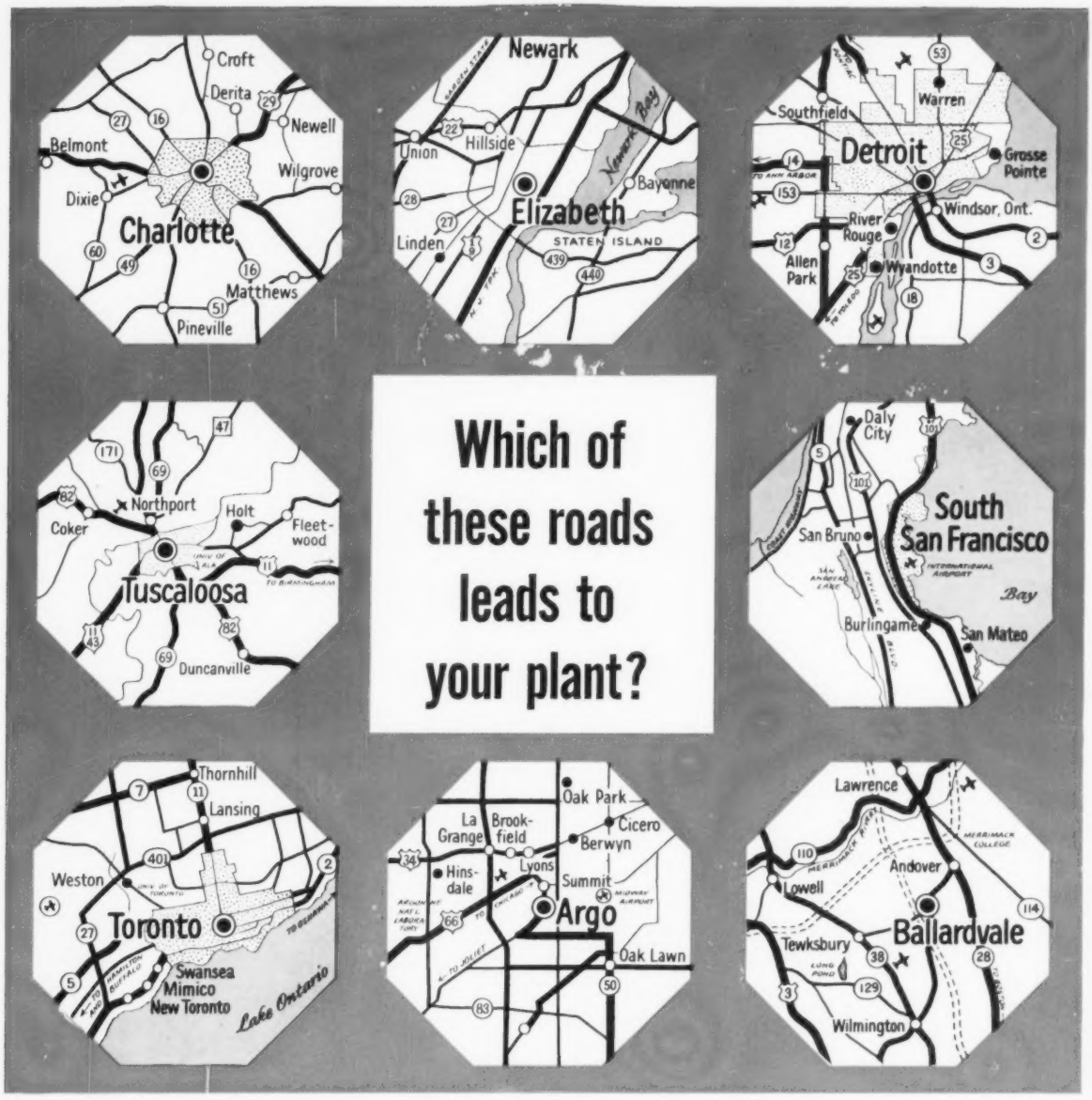


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Is fast, dependable delivery of quality foundry binders important to your production? Reichhold now ships from eight strategically located plants and/or bulk storage points — more than any other producer. The plants are located at: Charlotte, N. C.; Elizabeth, N. J.; Detroit, Mich.; Tuscaloosa, Ala.; So. San Francisco, Calif.; Ballardvale, Mass.; Toronto, Ont. (Reichhold Chemicals, [Canada] Ltd.); bulk storage facilities at: Argo, Ill.

Equally important, Reichhold's experience in the foundry resin field is an assurance that RCI phenolics and amino-aldehydes can satisfy any of your core sand mixture requirements.

Why not contact your Reichhold representative for more information on RCI foundry products.

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FOUNDRY PRODUCTS

FOUNDREZ — Synthetic Resin Binders
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